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KEELSON
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DP CPD LEARNING MANUAL

Continuing Professional Development (CPD) for Revalidating Nautical Institute DP Operator and Vessel Maintainer Certificates

ACCREDITED BY The Nautical Institute

Quality ISO 9001 www.dekra-seal.com DEKRA certified

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FORWARD

Welcome to the DP CPD training manual. My name is Mat Bateman, and I hope this information proves valuable whether you are a DP CPD participant or seeking general DP knowledge.

This third revision marks eight years since the DP CPD program began. Initially used to evaluate surveyors for DP assurance, the program has evolved and is now used by owners, operators and independent DPO certified officers. Since 2019, it has been formally recognized by the Nautical Institute for DP CPD.

With this new revision of the DP Learning Manual (formerly the Primer), we have implemented a few changes. Throughout 2025, we will supplement this material with bite-size learning initiatives on social media and the Keelson app.

Please reach out to us at info@keelsonmarine.com if you need assistance understanding the requirements, or if you have any comments or feedback. I always value the opportunity to connect with participants – it's a personally rewarding aspect of the program.

Good luck to those currently undertaking DP CPD. For those seeking broader DP information, I hope you find what you're looking for.

In closing, I would like to recognize the following individuals for their support of the DP CPD:

- Elizabeth Dann, for managing the program
- Kate Gillespie, for her efforts in developing and supporting the program, including the first revisions of this document
- Steve Sandercott, for his technical QA

Mat Bateman

Senior Partner, Keelson Marine Assurance

Houston, Tx. January 2025

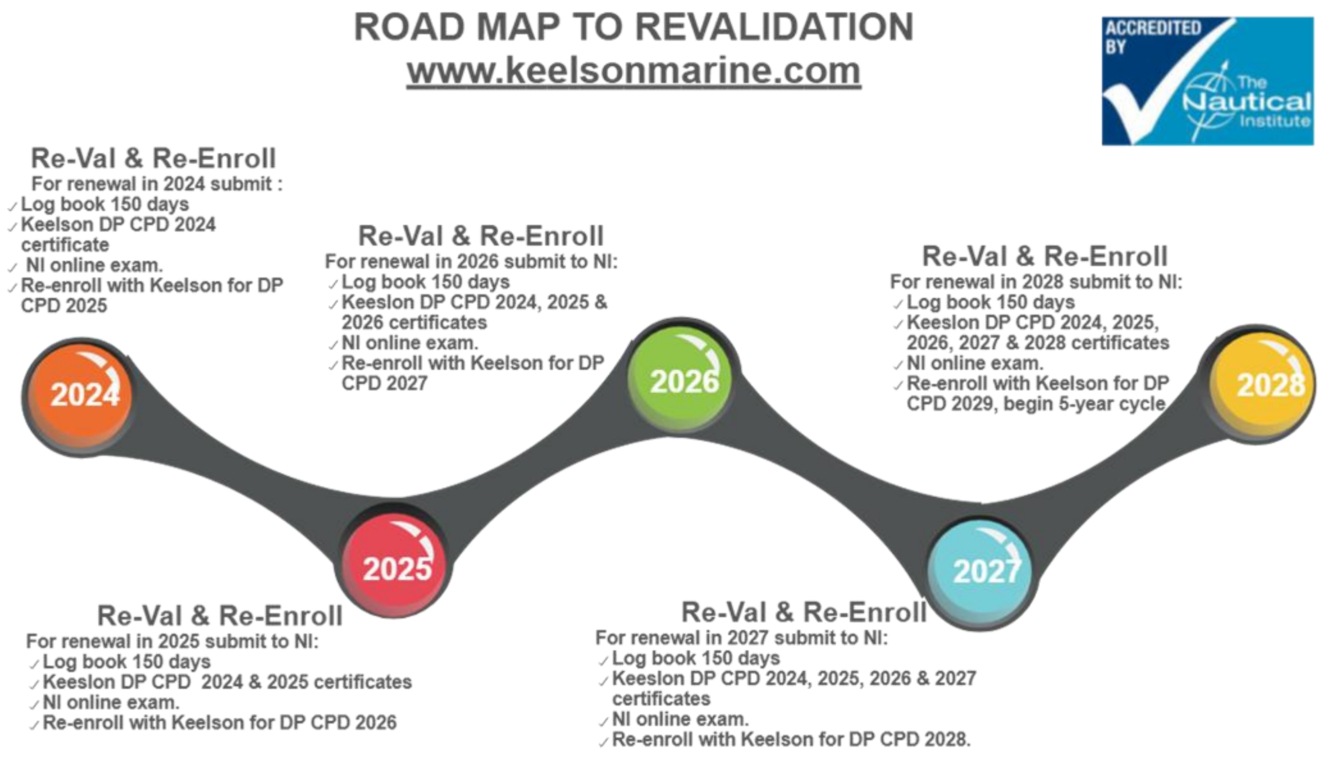

FIGURE 1 - ROAD MAP TO REVALIDATION

The above shows the path to revalidation using DP CPD. Review the year you are due for revalidation and review what you need to use the DP CPD route for revalidation. If you have any concerns please contact us at info@keelsonmarine.com . We are here to help.

THE NI DP CPD PROCESS

Keelson Marine Assurance LLC are accredited by the Nautical Institute to deliver DP CPD and our annually issued certificates are accepted by the Nautical Institute for DP officers revalidating their Nautical Institute DP Operator and Vessel Maintainer certificates.

This DP Learning Manual supports Keelson's DP CPD programme and is a highly recommended tool to be used in conjunction with the online formative assessment process. Only after engagement with the annual online formative assessment process, will a certificate be issued that can be submitted to the Nautical Institute for the purpose of revalidating DP Operator and Vessel Maintainer certificates.

Keelson has a Power B.I link to with the Nautical Institute so the NI can automatically see your Keelson CPD records when you come to revalidate your DPO or DPVM certification.

PROCEDURE

1. The company/candidate approach Keelson and enrol their officers (i.e. deck, engineering and electro technical DP officers) on Keelson's Nautical Institute accredited DP CPD programme.
    a. If your company is not engaging with Keelson's DP CPD programme for you, we do have a mechanism that supports individual enrolment. Email assessment@keelsonmarineassurance.com for more information or enrol through our website at www.keelsonmarine.com
2. Keelson enrols each candidate onto the online DP CPD assessment for learning programme hosted by Cirrus
    a. Keelson's online DP CPD assessment for learning programme is mapped against the key personnel roles and competence levels as defined in IMCA M117 Chapter 7 and against MTS PDDP2
    b. The pathway you follow through our assessment process depends on your role and your rank according to IMCA M117, i.e. masters will get a harder set of questions than DPOs, and chief engineers will get a different set of questions than masters.
3. Upon enrolment candidates take a baseline assessment. A detailed report indicating areas of strength and weakness is generated immediately.
    a. Candidates use their personal report, this Learning Manual, the DP app, and published industry guidance, to self-study indicated areas of weakness. This DP Learning Manual meets the requirements of Appendix 2 of the Nautical Institute's document *Annex K Continuing Professional Development (CPD) for revalidating for The Nautical Institute DP Operator certificate and DPVM certificates* ACCREDITATION STANDARD 2023 Version Draft Effective Date 01 January 2023
    b. Appendix 2 does not differentiate between roles and ranks on board as defined in IMCA M117 and MTS PDDP2. Therefore, we issue the same document to all enrolled officers regardless of role or rank onboard.
    c. Appendix 2 identifies topics that are to be covered in the five yearly DP CPD cycle. This Learning Manual is compiled in module order.
4. Candidates log back into Cirrus and take the second assessment and see how they have improved. To get your certificate we must see some POSITIVE improvement. Be aware, that there are mechanisms in place to identify those who do not engage genuinely in the baseline assessment.
5. On completion of the second online DP CPD assessment for learning, Keelson issues the candidate a certificate of CPD engagement for the purpose of revalidating DP Operator and Vessel Maintainer certificates.
6. Company BI (Business Intelligence) interfaces are automatically updated at least every 24 hours.

7. Keelson's systems have an API with the Nautical Institute Alexis system so the NI can automatically see your Keelson CPD records when you come to revalidate your DPO or DPVM certification.

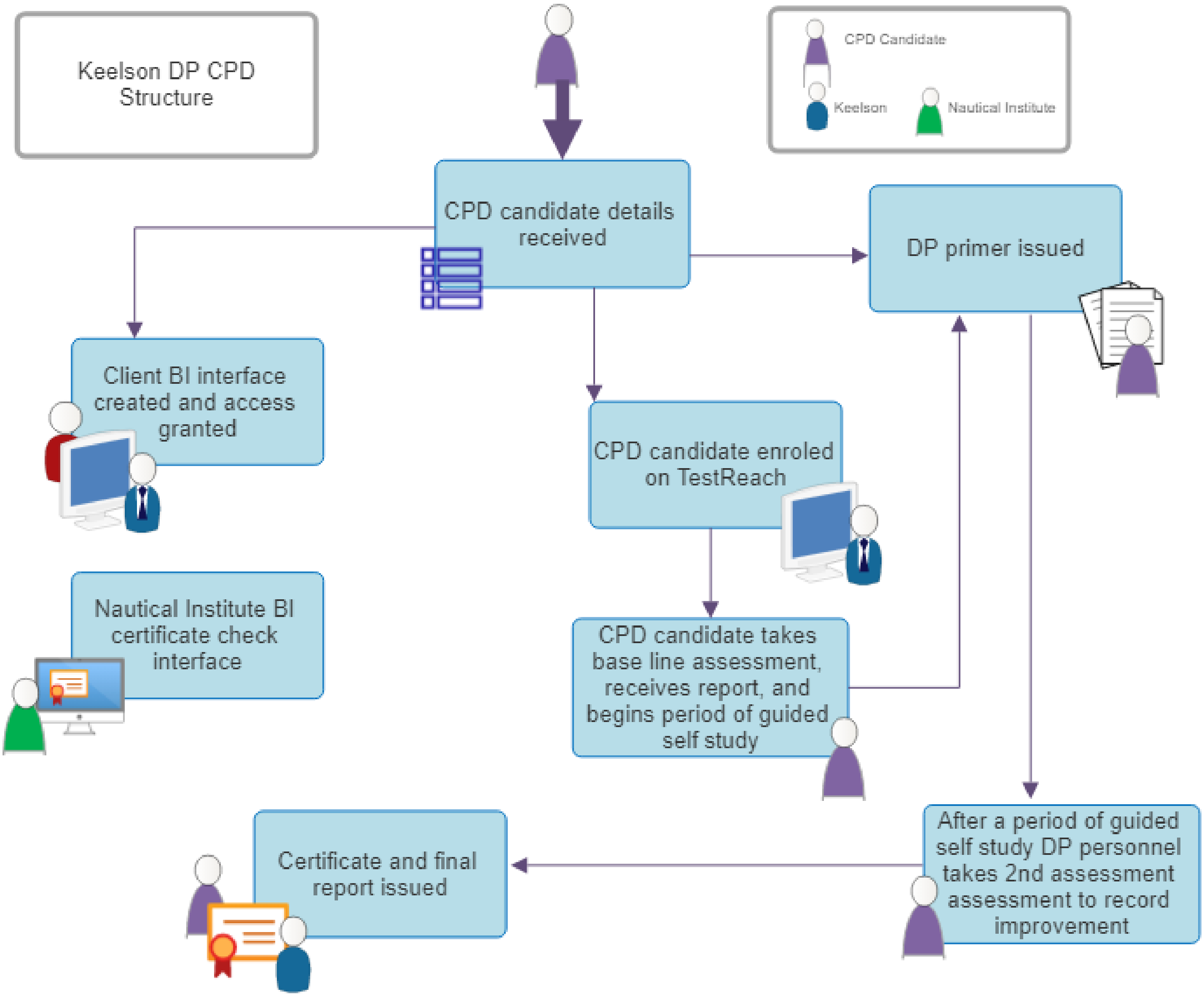

FIGURE 2 - KEELSON CPD PROCESS

THIS IS A REFERENCE DOCUMENT FOR ALL FIVE YEARS OF NAUTICAL INSTITUE CPD. IT IS WRITTEN TO SUPPORT YOU THOUGH THE PROCESS AND FOR YOUR WIDER REFERENCE.

At all times we recommend you access the industry source document in full.

This DP Learning Manual supports Keelson's DP CPD programme and supports our online formative assessment process. Only after engagement with the annual online formative assessment process will a certificate be issued that can be submitted to the Nautical Institute for the purpose of revalidating DP Operator and Vessel Maintainer certificates.

Before you engage with any of the chapters below log in to Cirrus and take the baseline assessment.

Using your baseline report to find, read, and analyse the specific industry document line items that require further examination and evaluate their meaning and application to your role, rank, vessel and current DP operation.

You can use this Learning Manual to contextualise these industry documents at a very basic level as required by the Nautical Institute (**Error! Reference source not found.**). There are links to online industry documents and to videos.

The Nautical Institute require CPD OR a revalidation course before DP certification can be revalidated every five years. That is, if CPD is not engaged in, the licenced DPO will have to do a four-day revalidation course ashore. The NI revalidation course must be at least 34 hours long. It is therefore surmised that CPD activities over five years must be at least 34 hours, or more than 7 hours every year for five years. This equates to roughly one working day per year.

We will draw on documents from right across the industry, not just those referenced in the Nautical Institute DP CPD Revalidation document, and 'expert pieces' written exclusively for us by leading DP experts.

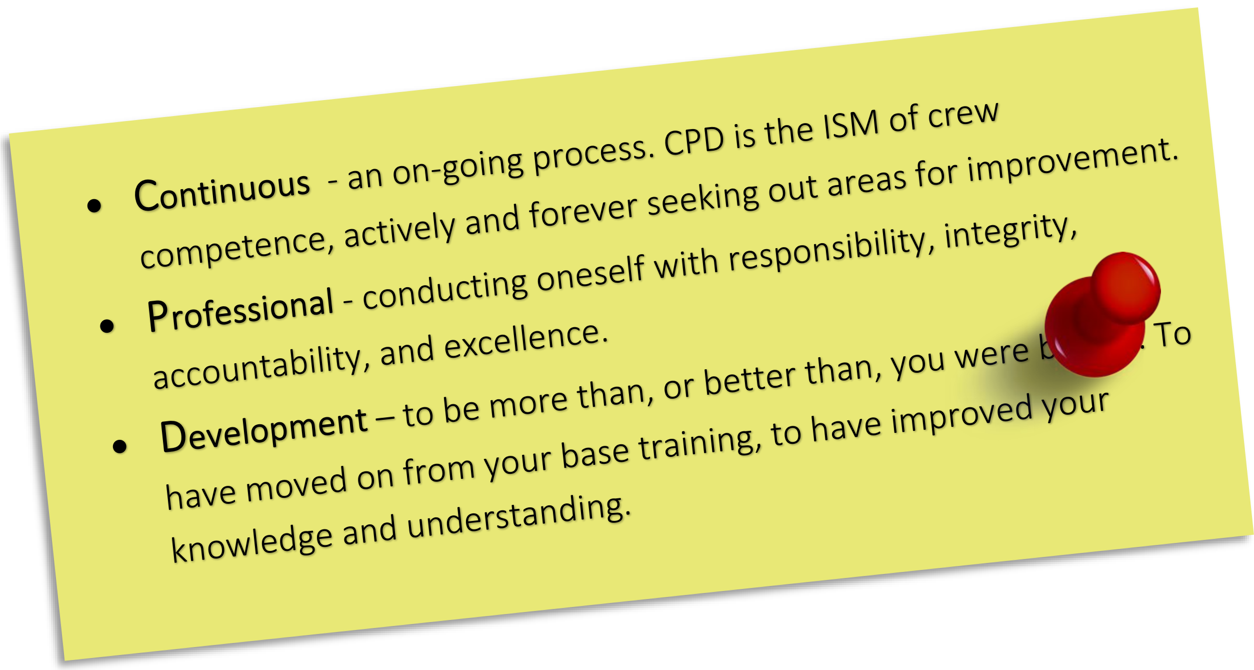

FIGURE 3 - CPD DEFINITION

PRACTICAL ONBOARD EXERCISES

At the end of each section you will find suggestions for practical onboard exercises as required by the Nautical Institute. These are not intended to take inordinate amounts of time and often they are designed to trigger a thought process or conversation onboard.

ABOVE AND BEYOND

Keelson's DP CPD is designed to take you above and beyond this basic level of knowledge and to create engaged, professional DP practitioners who really are at the top of their game. To that end we have included an **'above and beyond'** component to each section that will guide you to documents and learning above that required for Nautical Institute accreditation.

The online formative assessments are based on documents from right across the industry, not just those referenced in the Nautical Institute DP CPD Revalidation document.

We may also refer you to 'expert pieces' written exclusively for us by leading DP experts that are available on our Dynamic Positioning app.

You will need to look at these sections before you log back into Cirrus and take your second assessment to see how much you have improved.

Core Module DP Regulations & Guidance
IMO - Introduction, purpose, highlights including IMO MSC/Circ. 645 and IMO Circ 1580
IMCA - Introduction, purpose, highlights
MTS - Introduction, purpose, highlights
MSF - inc, GOMO / MSF182
Class Rules - Introduction, purpose, highlights
Flag State - Introduction, purpose, highlights
Regulatory updates in the last 12 months
New or update publications and bulletins in the last 12 months
Management of change - The importance, lessons learned through station keeping events.
IMCA DP Station keeping Event Reporting Scheme
Lessons learned from DP Station Keeping Events
DP Emergency Drills and Scenarios - Rules, guidance, purpose, results criteria, (examples annually)
Roles & Responsibilities of Key DP personnel (according to M117)
DP Testing & Trials
FMEA
FMEA - purpose, class & guidance requirements, class involvement, specific guidance, objectives, failure types (single, common, hidden, etc)
FMEA Proving trials - guidance, purpose, requirements, what should be demonstrated (redundancy concept, effectiveness of protective functions, stability of the system over full range of load conditions, monitoring functions, degraded and failure condition, etc.)
FMEA 5 years proving trials - purpose, requirements, guidance, what should be demonstrated, etc
DP Annual Trial
IMCA M190, purpose, class & guidance requirements, class involvement, specific guidance, objectives, IMCA DP Practitioner Accreditation Scheme
Field Arrival Trials
Guidance, purpose, requirements, what should be demonstrated
DP Networks (Move to DP System)
DP Network system - overview & the risks, guidance available
DP Network system - Operational & Failure considerations
DP Network system - Lessons learnt from DP Events DP Network system
Redundancy Concepts
Worse Case Failure (WCF) & Worst Case Failure Design Intent (WCFDI) - explained
DP Capability plots - Purpose, IMO / Class requirements.
Open/closed bus operations - Rules, guidance, considerations, risks,
Configuration - The importance of the FMEA, consequences of configuration errors
Cross Connections - the risks and managing those risks
DP Position Reference Systems and Sensors
Introduction to Position References & Sensors
Different Principles including relative & absolute and general challenges

e.g., blocking of signals
Considerations for appropriate selection of PRS for DP operations
PRS Interaction and calibrating PRS
PRS Lessons learnt from DP events
DGNSS
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Laser
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Laser (No Reflector)
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Microwave
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Hydroacoustic
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
INS
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Taut Wire
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Gangway Sensors
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Wind Sensor
Overview, advantage, disadvantage, inc. how wind profiles can be affected by assets
Operational & Failure considerations
Lessons learnt from DP Events

New developments in last 5 years
Heading Sensor
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events INS
New developments in last 5 years
MRU / VRU
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events MRU
Current Sensor
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events DGNSS
New developments in last 5 years
Tension Sensor
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events Tension sensor
New developments in last 5 years
Draft Sensor
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events Draft sensor
New developments in last 5 years
DP System Computer, Controllers, Network, IJS
General
DP System Computer, Controllers - Overview inc. controllers & operator stations
DP System Computers and controllers- Lessons learnt from DP Events
Mode changes (Auto to Manual, etc) - considerations and lessons from DP station keeping events
IJS Overview
Rules & guidance
Power supplies - Redundancy philosophy
Location of control station
Exercises & Drills
Power and Power generation Systems and UPS
General
Power Management (e.g. General requirements / impact of mission equipment (e.g. effect on station keeping capability), operating within capability)
Blackout Prevention
Load dependent Starting & stopping of power generation
Power generation - basics of frequency & voltage control (active & reactive power)
Open and Closed Bus operation
Short circuit testing
Power limit – As per IMO 1580
Hybrid Battery systems - Guidance, concept, principles, risks

UPS - following redundancy, the requirements of operation
DC Grids
Lessons Learnt
Thrusters and Thruster control systems
Thrusters - Overview
Thruster types - Overview, advantage, disadvantage
Thruster allocation / Modes of operation - e.g. bias and considerations therein
Thruster control system - the basics including EM stops and emergency/Backup controls
Thrusters - Failure modes and their effects on operations
Lessons learnt from DP Events
New developments in last 5 years
DP Operations
Operational Planning & Decision Support Tools
General operational planning – configuration of DP systems (CAM / TAM) and ASOG to define operational, environmental and equipment performance limits applicable when operating vessel and provide guidance on actions in the event of these limits being exceeded.
DP alert light system
DP setup procedures
DP watch keeping procedures
Environment conditions
DP Operations Manual
Layout of company standard operating procedures and Vessel specific DP operating procedures
DP Logs and Checklists
Purpose, overview of expectations / requirements
Capability Plots and Footprint plots
Simultaneous Operations (SIMOPS)
Considerations for simultaneous operations involving DP and non DP vessels
Mission Specific Operations
General Considerations
Introduction to different mission types & available guidance
The mission - its interaction with DP redundancy concept (load limitation priorities, sharing of common supplies (e.g., power, cooling, ventilation), DP3 F&F integrity of mission equipment, draught changes (e.g. heavy lifts), wind profile, blocking of PRS signals
Reference systems & Sensors (general considerations from a mission perspective)
Operational planning (general considerations from a mission perspective)
Dive Support Vessels
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission Operational Considerations & Planning - specific to mission
Pipe Lay/Cable Lay
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
ROV Support

General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
Heavy Lift
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
Float Over
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
Accommodation
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
Drilling
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
FPSO Floating Production Storage and Offloading Unit
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
Shuttle Tankers
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission

MAIN TOPICS

This Learning Manual covers the main topics shown below.

This section contains information on the following topic areas as defined by the Nautical Institute.

Core Module DP Regulations & Guidance
IMO - Introduction, purpose, highlights including IMO MSC/Circ. 645 and IMO Circ 1580
IMCA - Introduction, purpose, highlights
MTS - Introduction, purpose, highlights
MSF - inc, GOMO / MSF182
Class Rules - Introduction, purpose, highlights
Flag State - Introduction, purpose, highlights
Regulatory updates in the last 12 months
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IMCA DP Station keeping Event Reporting Scheme
Lessons learned from DP Station Keeping Events
DP Emergency Drills and Scenarios - Rules, guidance, purpose, results criteria, (examples annually)
Roles & Responsibilities of Key DP personnel (according to M117)

THE IMO – INTRODUCTION AND PURPOSE

IMO – the International Maritime Organization – is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships.

As a specialized agency of the United Nations, IMO is the global standard-setting authority for the safety, security and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and implemented.

IMO measures cover all aspects of international shipping – including ship design, construction, equipment, manning, operation and disposal – to ensure that this vital sector for remains safe, environmentally sound, energy efficient and secure.

IMO treaties need to be implemented into national law so that they can be applied on ships flying the flag of a particular country and so that those countries can implement effective Port State Control and comply with other obligations under the specified IMO instruments.

IMO AND DYNAMIC POSITIONING

There are four main IMO conventions that refer to dynamic positioning:

1. STCW;
2. IMO MSC.1/Circular 738/Rev.2;
3. IMO MSC/Circular 645 Guidelines for Vessels with Dynamic Positioning Systems – (Adopted on 6 June 1994);
4. IMO MSC/Circular 1580 Guidelines for Vessels with Dynamic Positioning (DP) Systems – (Adopted on 16 June 2017)

1. STCW INTERNATIONAL CONVENTION ON STANDARDS OF TRAINING, CERTIFICATION AND WATCHKEEPING FOR SEAFARERS

It may surprise you to learn that the IMO's standards for the training and experience for personnel operating dynamic positioning systems are in section B of STCW, the guidance section (see page 329 of STCW). That is, there is no MANDATORY requirement for any flag state to implement training for personnel operating dynamic positioning systems laid out in STCW. The guidance recommends that training and experience for personnel operating dynamic positioning systems cover the following components of a DP system:

.1 DP control station;

.2 power generation and management;

.3 propulsion units;

.4 position reference systems;

.5 heading reference systems;

.6 environmental reference systems; and

.7 external force reference systems, such as hawser tension gauges.

2. IMO MSC.1/CIRCULAR 738/REV.2 GUIDELINES FOR DYNAMIC POSITIONING SYSTEM (DP) OPERATOR TRAINING

However the IMO released circular 738 in June 2017 that requested all Member States to bring an IMCA document, ***IMCA M 117 Rev.2 "Training and Experience of Key DP Personnel"*** to the attention of all parties concerned. This document identifies training programmes, levels of competency and experience for the safe operation of DP vessels and is covered later in this Learning Manual.

3. IMO MSC/CIRCULAR 645 GUIDELINES FOR VESSELS WITH DYNAMIC POSITIONING SYSTEMS – (ADOPTED ON 6 JUNE 1994)

This document is valid for vessels and units constructed on or after 1 July 1994 but before 9 June 2017

The purpose of this set of guidelines is to recommend **design criteria, necessary equipment, operating requirements, and a test and documentation system** for dynamic positioning systems to reduce the risk to personnel, the vessel, other vessels or structures, sub-sea installations and the environment while performing operations under dynamic positioning control.

The responsibility for ensuring that the provisions of this set of guidelines are complied with rests with the **owner** of the DP vessel.

These guidelines have a preamble and five chapters:

Preamble

1. *General*
   This includes definitions that we will explore in detail in later modules.
2. *Equipment Classes*
   A very important chapter that defines how components and systems should act together to achieve reliable position keeping capability. The larger the consequence, the more reliable the DP-system should be and to achieve this philosophy the requirements have been grouped into three equipment classes. We will explore the capabilities of each equipment class in later modules.
3. *Functional Requirements*
   Another very important chapter that is broke down into six sub chapter. Each sub chapter contains guidelines for the design, construction, and testing of components in a DP system as follows.
   3.1 General
   3.2 Power system
   3.3 Thruster system
   3.4 DP-control system
   3.5 Cables and piping systems
   3.6 Requirements for essential non-DP-systems
   We will explore the guidelines for the design, construction, and testing of these components later.
4. *Operational Requirements*
   This chapter offers guidance on checking the vessels DP set up before DP operations according to a vessel specific “location" check list to make sure that the DP-system is functioning correctly and that the system has been set up for the appropriate equipment class.
5. *Surveys, Testing and the Flat State Verification and Acceptance Document (FSVAD)*
   The requirements for four separate surveys are defined in this chapter
   1 Initial
   2 Periodical
   3 Annual survey
   4 Post defect, accident, repair, alteration survey

4. IMO MSC/CIRCULAR 1580 GUIDELINES FOR VESSELS WITH DYNAMIC POSITIONING (DP) SYSTEMS – (ADOPTED ON 16 JUNE 2017)

These guidelines apply to vessels and units constructed **on or after 9 June 2017** (vessels and units constructed on or after 1 July 1994 but before 9 June 2017 may continue to apply IMO MSC/Circular .645 **however it is recommended that section 4 of the present Guidelines be applied to all new and existing vessels and units, as appropriate.**

As with IMO MSC/Circular. 645 the purpose of this set of guidelines is to recommend ***design criteria, necessary equipment, operating requirements, and a test and documentation system*** for dynamic positioning systems to reduce the risk to personnel, the vessel, other vessels or structures, sub-sea installations and the environment while performing operations under dynamic positioning control.

The responsibility for ensuring that the provisions of this set of guidelines are complied with rests with the **owner** of the DP vessel.

These guidelines have a preamble and **SIX** chapters:

Preamble

1. *General*

This includes definitions that we will explore in detail in later modules.

2. *Equipment Classes*

A very important chapter that defines how components and systems should act together to achieve reliable position keeping capability. The larger the consequence, the more reliable the DP-system should be and to achieve this philosophy the requirements have been grouped into three equipment classes. We will explore the capabilities of each equipment class in later modules.

3. *Functional Requirements*

Another very important chapter that is broke down into six sub chapter. Each sub chapter contains guidelines for the design, construction, and testing of components in a DP system as follows.

3.1 General
3.2 Power system
3.3 Thruster system
3.4 DP control system
3.5 Cables and piping
3.6 Requirements for essential non-DP systems
3.7 Independent joystick system

We will explore the guidelines for the design, construction, and testing of these components in later modules.

4. *Operational Requirements*

This chapter ideally applies to ALL DP vessels regardless of when they were built. It goes beyond the need for DP operations set up checks and introduces decision support tools such as an Activity Specific Operation Guide (ASOG) in order to make sure that the DP system is functioning correctly and that the system has been set up for the appropriate mode of operation. It also requires the production of DP capability polar plots to demonstrate position keeping capacity for fully operational and post worst-case single failure conditions. We will explore ASOGs and DP capability polar plots in later modules

5. *Surveys, Testing and the Flat State Verification and Acceptance Document (FSVAD)*

The requirements for four separate surveys are defined in this chapter

1 Initial
2 Periodical
3 Annual survey
4 Post defect, accident, repair, alteration survey

as well as the need for an FMEA in equipment class 2 and 3 vessels

6. TRAINING

Personnel engaged in operating a DP system should have received relevant training an practical experience in accordance with the provisions of the 1978 STCW Convention, as amended, the STCW Code, as amended, and the Guidelines for Dynamic Positioning System (DP) Operator Training (MSC/Circ.738, as amended).

This is an additional chapter and is quoted above in its entirety. Note that it takes us back to STCW, and to IMO MSC/Circ. 738 that requested all Member States to regard IMCA document, IMCA M 117 Rev.2 "Training and Experience of Key DP Personnel" we will explore IMCA M 117 later.

PRACTICAL ONBOARD EXERCISE

Download the Keelson Dynamic Positioning app by visiting Google Play or Apple App Store and searching for ***Dynamic Positioning***, or scanning this QR code. Here you will find all the industry documents that you will need to for this CPD programme EXCEPT any IMCA related documents that are restricted to IMCA members only. If you do not want to download this app we recommend that you create your own DP Document 'brief case' by creating a folder on your computer and saving the documents via the links provided as you work through this document.

ABOVE AND BEYOND

Remembering that Keelson's DP CPD programme will take you above and beyond the Nautical Institutes CPD for revalidation requirements you will notice that the app contains links to a wide range of industry documents, not just these reference in the Nautical institute DP CPD revalidation standard. We are NOT asking you to read or regurgitate all of these documents now! We will guide you through their use in the following sections.

This Learning Manual is designed to support our online formative assessment processes you should have already logged into Cirrus and taken the first base line assessment and received your initial report.

Look at you report now. Remember you are not expected to move all of the dials all in one go, rather choose one or two areas to explore. You can do this alone, in partnership with a crew mate, or in your on-board departmental teams as part of a training matrix. Take one or two sections from the documents listed on your reports to look at and: -

- read it
- question it
- apply it to your vessel and experiences
- argue about it
- argue WITH it!

All the time you will be learning about it. If you learn one more thing, you will get at least one more question right next time and gradually, incrementally you will improve.

IMCA – INTRODUCTION AND PURPOSE

The International Marine Contractors Association (IMCA) is a trade association representing contractors and the associated supply chain in the offshore marine construction industry worldwide.

IMCAs purpose is to enable the development of the world's marine energy resources – safely and sustainably. Their mission is to improve performance in the marine contracting industry.

To achieve this they hold conferences, seminars, and a network of committees. They represent their members with other industry bodies, regulators, oil companies and renewable energy companies.

IMCA AND DYNAMIC POSITIONING

IMCA's marine DP committee co-ordinates work items relating to dynamic positioning. They provide expert advice in all matters pertaining to dynamic positioning and are responsible for managing all IMCA DP guidance documents and initiatives.

IMCA PUBLICATIONS

IMCA's technical library represents a considerable body of work but the intellectual property rights belong to its members. IMCA's Board has determined that IMCA's documents, "developed by our members for our members", should no longer be available for purchase by non-members. Your company may be an IMCA member. If they are it is your company who will supply you with access to IMCA documents. For a list of the documents you are not allowed to see unless you, or your company, are a member click here.

PRACTICAL ONBOARD EXERCISE

Ask your employer if they are a member of IMCA. If they are, ask them how you, as a DP practitioner can access IMCA's technical library. If your employer is not an IMCA member, ask them how they can support you in accessing IMCA's technical library. You will need to access these documents to progress with the Nautical Institute DP CPD standard.

MTS - INTRODUCTION, PURPOSE, HIGHLIGHTS

The Marine Technology Society is a trade association like IMCA, promoting awareness, understanding, and the advancement and application of marine technology. It brings together businesses, institutions, professionals, academics, and students who are ocean engineers, technologists, policy makers, and educators.

Their mission is to facilitate a broader understanding of the relevance of marine technology to wider global issues by enhancing the dissemination of marine technology information. They promote and improve marine technology and related educational programs. Their vision is to be the leading authority and advocate for marine technology and resources while promoting member success and public understanding.

The DP Committee was established in 1996, with the objective of promoting a greater international understanding of Dynamic Positioning and related issues.

The Dynamic Positioning Committee's mission is to encourage exchange of information, discussion of technology, training and education, foster improvement of DP reliability, develop guidelines, and address any other issues pertinent to dynamic positioning that facilitate incident free execution of DP operations.

Like IMCA, MTS also produce DP industry guidance, but unlike IMCA this is freely available. Keelson's DP CPD is not only accredited by the Nautical Institute for DP CPD revalidation but it is also recognised as meeting the needs of MTS PDDP 2.

MARINE TECHNOLOGY SOCIETY GUIDANCE FOR PROFESSIONAL DEVELOPMENT OF DP PERSONNEL (PDDP2)

PDDP 2 is MTS's version of IMCA's M 117. The aim is to:

> *to address the People element. It is focused on enabling the development of DP awareness, knowledge and skills of multi-disciplinary Vessel Operational teams and by doing so facilitates delivery of incident free DP operations.*

PDDP2 identifies nine roles or ranks onboard DP vessels and identifies the three levels of learning within them.

> *AWARE: Able to explain, describe, discuss, identify, locate and report on the area of knowledge and its relevance, potential impact and consequences to the operations associated with the industrial mission.*
>
> *KNOWLEDGEABLE: Able to demonstrate understanding of the terminology and vocabulary in the area of knowledge. Able to demonstrate understanding of the operations associated with the industrial mission and potential impact, consequences. Able to execute planned procedures. Able to plan, prioritize and adapt to evolving situations.*
>
> *SKILLED: Able to translate guidelines and standards in the area of knowledge and its relevance to the operations associated with the industrial mission and potential impact, consequences into practical actions. Able to develop, review and modify procedures in the area of knowledge. Able to evaluate, differentiate, discriminate, validate and communicate solutions to common technical and operational problems. Provide mentorship and training in the area of knowledge, relevant to the industrial mission.*

It is the aim of Keelson's DP CDP to raise all DP practitioners to a SKILLED level. Remember our CPD programme will take you above and beyond the requirements for the Nautical Institutes revalidation requirements.

MTS guidance addresses is constructed on the *three legged stool* concept of design, operations and people. This is supplemented with a wealth of technical and operational guidance notes. We will refer to these documents throughout this Learning Manual, and your DP CPD base line assessment report will also require you to engage with them.

These documents are freely available by clicking in the table below, the MTS website, and via the Dynamic Positioning app.

Design	Operations	People
DP Vessel Design Philosophy Guidelines April 2021	DP Operations Guidance - Part 1	Guidance for Professional Development of DP Personnel (PDDP2)
DP Vessel Design Philosophy Guidelines Appendix B DP Shuttle Tanker Redundancy Concept Philosophy Document April 2021	DP Operations Guidance - Part 2 - Appendix 1 - MODUs	
	DP Operations Guidance - Part 2 - Appendix 2 - Project Construction Vessels	
	DP Operations Guidance - Part 2 - Appendix 3 - Logistics Vessels	

MTS have also produced documents they categorise as 'Technical and Operational Guidance Notes' referred to as 'TechOps' allocated to 4 section – General (G), Design (D), Operations (O), People (P)

For access to the web page – click here

GENERAL (G)	TECHOP (G-01 - Rev1 - Jan21) - TECHOP PHILOSOPHY
	TECHOP (G-02 - Rev1 - Jan21) - Power Plant Common Cause Failures
	TECHOP (G-03 - Rev1 - Jan21) - Continuous Trials for DP MODUs
	TECHOP (G-04 - Rev1 - Jan21) - Conducting Effective and Comprehensive DP Incident Investigations
DESIGN (D)	TECHOP (D-01 - Rev1 - Jan21) - ADDRESSING C^3EI^2 TO ELIMINATE SINGLE POINT FAILURES
	TECHOP (D-02 - Rev1 - Jan21) - FMEA Testing
	TECHOP (D-03 - Rev1 - Jan21) - Blackout Recovery
	TECHOP (D-04 - Rev1 - Jan21) - Evaluation of Protection Systems
	TECHOP (D-05 - Rev1 - Jan21) - FMEA Gap Analysis
	TECHOP (D-06 - Rev1 - Jan21) - DGNSS Position Reference Sensors
	TECHOP (D-07 - Rev1 - Jan21) - A Method for Proving the Fault Ride-Through Capability of DP Vessels with HV Power Plant
	TECHOP (D-08 - Rev1 - Jan21) - Software Testing
	TECHOP (D-09 - Rev1 - Jan21) - PRS AND DPCS HANDLING OF PR)
	TECHOP (D-10 - Rev1 - Jan21) - DNV RP D102 FMEA GAP ANALYSIS)
	TECHOP (D-11 - Rev1 - Jan21) - REDUNDANCY CONCEPT PHILOSOPHY DOCUMENT – in progress
OPERATIONS (O)	TECHOP (O-01 - Rev1 - Jan21) - DP Operations Manual
	TECHOP (O-02 - Rev1 - Jan21) - Annual DP Trials and Gap Analysis
	TECHOP (O-03 - Rev1 - Jan21) - Defining Critical Operations Requiring Selection of Critical Activity Mode
PEOPLE) (P)	TECHOP (P-01 - Rev1 - Jan21) - Part 1 - DP SME and FMEA Practitioner Competency Elements
	TECHOP (P-01 - Rev1 - Jan21) - Part 2 – Competency Elements for DP Professionals – DP SMEs / DP FMEA Practitioners –
	TECHOP (P-01 - Rev1 - Jan21) - Part 3 - Competency Elements for DP Professionals - DP SMEs / DP FMEA Practitioners –

PRACTICAL ONBOARD EXERCISE

Make sure you have access to all the above named MTS documents either by way of the Keelson Dynamic Positioning app or via the MTS website.

ABOVE AND BEYOND

Access MTS PDDP 2 and refer to section 3.9 Enabling Effectiveness of this Guidance and PDDP2 and read section 3.9.4. Compare the rationale of this CPD programme with behaviours encouraged in this section.

Look at your role and rank onboard in the PDDP2 Tool and check the levels of learning required for each of the knowledge areas.

The Marine Safety Forum is a non-profit-making organisation that started as the North Sea Marine Affinity Group in 1997. It actively promotes safety within the marine sector of the offshore energy industry. The membership comprises ship-owning / managing companies, logistics companies, energy sector operators, marine consultants and other interested parties (e.g. port authorities, trade associations, governmental agencies, ship-brokerages)

MSF AIMS

to improve safety within the marine sector of the offshore energy industry

MSF OBJECTIVES

- *To air marine safety issues in an open forum of service users and providers*
- *To highlight areas of particular concern and reach consensus on action required to minimise risk of major incidents.*
- *Take pre-emptive action on minor issues which have the potential to escalate*
- *To represent marine concerns within the "Step Change in Safety" initiative.*
- *To work together with industry to share safety information and good practice.*

The MSF has several publications applicable to DP practitioners that are freely available from the table below, the MSF website, and via the Keelson Dynamic Positioning app. The most notable of these is MSF 182, or "GOMO - *Guidelines for Offshore Marine Operations"* which although is mostly refers to only in the North Sea area is of interested to globally serving DP practitioners. It was created in conjunction with IMCA.

International Guidelines for the Safe Operation of Dynamically Positioned Offshore Supply Vessels	Delivering Quality Potable Water to Offshore Installations – Rev 03	The Carriage of Methanol in Bulk Onboard Offshore Vessels
500m Safety Zone	Delivering Quality Bulk Marine Gasoil to Offshore Installations	Tandem Loading Guidelines
Marine Operations – 500m Zone		

PRACTICAL ONBOARD EXERCISE

Make sure you have access to all the above named MSF documents wither by way of the our Dynamic Positioning app or via the MSF website.

ABOVE AND BEYOND

Access GOMO and refer to section 3.3 Key DP Personnel Continuous Professional Development. Consider how this is being implemented in your present company and what improvements could be developed to better meet MSF's aims.

CLASS RULES - INTRODUCTION, PURPOSE, HIGHLIGHTS

A ship classification society is a non-governmental organization that establishes and maintains technical standards for the construction and operation of ships and offshore structures. Classification societies certify that the construction of a vessel comply with relevant standards and carry out regular surveys in service to ensure continuing compliance with the standards.

Currently, more than 50 organizations describe their activities as including marine classification, twelve of which are members of the International Association of Classification Societies.

CLASS AND DP

Most classification societies use the IMO MSC/Circ. 645 or IMO MSC/Circ. 1580 principles of equipment class and redundancy requirements as the basis for their own DP rules.

The table below provides an overview of three major classification societies DP class notations and the equivalent IMO DP equipment classes.

Description	IMO DP Class	ABS DP Class	LRS DP Class	DNV DP Class
Manual position control and automatic heading control under specified maximum environmental conditions.		DPS-0	DP (CM)	DPS 0 DYNPOS-AUTS
Automatic and manual position and heading control under specified maximum environmental conditions.	Class 1	DPS-1	DP (AM)	DPS 1 DYNPOS-AUT
Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault excluding loss of a compartment. (Two independent computer systems).	Class 2	DPS-2	DP (AA)	DPS 2 DYNPOS-AUTR
Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault including loss of a compartment due to fire or flood. (At least two independent computer systems with a separate back-up system separated by A60 class division).	Class 3	DPS-3	DP (AAA)	DPS 3 DYNPOS-AUTRO

Many of 12 IACS Classification Societies issue certificates to DP vessels. Although each set of rules are based on IMO MSC/Circ. 645 or IMO MSC/Circ. 1580 they will have differences. The table below provides links to the DP documentation of each of these class societies (others are available via the internet).

ABS	LRS	DNV
Guide for Dynamic Positioning Systems	Rules and Regulations for the Classification of Ships.	Rules and Standards Explorer
BV		
Rules for classification of steel Ships NR467 – July 2023 (Part F – Ch 11 Sec 5)		

To obtain the documentation from DNV it is necessary to sign in to 'Veracity' by creating a User name and password.

Note that DNV has also a set of notations DPS-1, DPS-2 and DPS-3 these are similar to the main notations but allow for thrusters to stop and restart following a fault.

Most of the societies now have 'enhanced' notations recognising where vessels may be over and above the minimum standards required. For example, below is the relevant extract from ABS:

> *The notation includes provisions for standby start, closed bus operation and transferable generators. These are beneficial to the overall environment, operational flexibility and system maintainability.*
>
> *Four separate enhanced notations are provided as follows:*
>
> - *Enhanced Electrical System (EHS-E): This notation covers the requirements for the electrical and power management systems that are beyond those for the DPS series notations.*
> - *Enhanced Power and Thruster System (EHS-P): This notation covers the requirements for the power system and thrusters that are beyond those for the DPS-series notations.*
> - *Enhanced Control System: (EHS-C): This notation covers the requirements on the DP control systems including control computers, position reference systems and sensors, which are beyond the minimum requirements for DPS-series notations.*
> - *Fire and Flood Protection System (EHS-F): This notation covers the requirements for fire and flood protection considering the risk level of the areas. This is a supplement for a DPS-2 system. It is not necessary for a DPS-3 system, since a DPS-3 system has higher requirement in this regard.*
>
> *The separate enhanced system notations provide the Owner with the flexibility of selecting an individual EHS notation or combined EHS notations that best fit the design intent.*

Also note that generally it will be the rules published at the time the vessel was built that will apply to your specific vessel. The rules may have been revised or updated and therefore the 'current' rules may be different.

An example is that some years ago two gyros was acceptable for some class societies DP2 equivalent, whereas now all would require three etc.

PRACTICAL ONBOARD EXERCISE

What classification society certificated your current DP vessel and what is it's class notation? We will be asking you to apply requirements disused in later sections directly to your vessel so it is important that you complete this exercise.

ABOVE AND BEYOND

Access the appropriate class rules for your vessel and save them on your computer for future reference.

FLAG STATE - INTRODUCTION, PURPOSE, HIGHLIGHTS

As well as their normal flag state responsibilities towards vessels under their jurisdiction MSC/Circ. 1580 requires them to issue a Dynamic Positioning Verification Acceptance Document (DPVAD) when a DP vessel is verified to be compliant. A DPVAD is valid for five years.

In practice, classification societies implement these requirements on behalf of flag state administrations as 'organisations duly authorised' but remember that it is the ultimate responsibility of the flag state or "Administration".

MSC/Circ. 1580 lists four different types of survey or testing requirements as follows:

1. *an initial survey which should include a complete survey of the DP system and FMEA proving trials for DP classes 2 and 3 to ensure full compliance with the applicable parts of the Guidelines. Furthermore it should include a complete test of all systems and components and the ability to keep position after single failures associated with the assigned equipment class. The type of tests carried out and results should be recorded and kept on board;*

2. *a periodical testing at intervals not exceeding five years to ensure full compliance with the applicable parts of the Guidelines. A complete test should be carried out as required in paragraph 5.1.1.1. The type of tests carried out and results should be recorded and kept on board;*

3. *an annual survey should be carried out within three months before or after each anniversary date of the Dynamic Positioning Verification Acceptance Document1. The annual survey should ensure that the DP system has been maintained in accordance with applicable parts of the Guidelines and is in good working order. The annual test of all important systems and components should be carried out to document the ability of the DP vessel to keep position after single failures associated with the assigned equipment class and validate the FMEA and operations manual. The type of tests carried out and results should be recorded and kept on board; and*

4. *a survey, either general or partial according to circumstances, should be carried out every time a defect is discovered and corrected or an accident occurs which affects the safety of the DP vessel, or whenever any significant repairs or alterations are made. After such a survey, necessary tests should be carried out to demonstrate full compliance with the applicable provisions of the Guidelines. The type of tests carried out and results should be recorded and kept on board.*

For equipment class 2 and 3 vessels MSC/Circ. 1580 also requires an FMEA to be carried out. Equipment classes and FMEAs are explored in subsequent sections of this Learning Manual.

PRACTICAL ONBOARD EXERCISE

Look at your vessels DPVAD and see who the issuing authority is.

Access MSC/Circ. 1580 section 5 - SURVEYS, TESTING AND DYNAMIC POSITIONING VERIFICATION ACCEPTANCE DOCUMENT (DPVAD) and read the requirements. According to MSC/Circ. 1580 section 5 when does a DPVAD cease to be valid?

ABOVE AND BEYOND

Access MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) section 4 and familiarise yourself with the stakeholders commonly involved in operating a DP vessel.

Table 3-1 Stakeholder Verification and Validation Responsibilities, consider column three 'Remarks' and create a further column applicable to your vessel.

This DP Learning Manual is intended to be used in conjunction with Keelson's FREE DP APP. The app is routinely updated with regulatory, new, or updated publications, and bulletins.

Simply search for Dynamic Positioning on the Google Play store or on Apple's App Store or scan this QR code.

GET IT ON Google play

Download on the App Store

FIGURE 4 - KEELSON APP

PRACTICAL ONBOARD EXERCISE

Download and register on the free app

ABOVE AND BEYOND

Take the DP CPD Just for Fun quiz

MANAGEMENT OF CHANGE - THE IMPORTANCE

An effective management of change process is critical at all stages of the DP vessels design construction and operation.

MANAGEMENT OF CHANGE IN DESIGN (MOC)

The MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) (chapter 8) advise that a robust management of change process should be established at the concept phase, implemented systematically and followed diligently throughout the build life cycle.

Keelson Observation - During the operational life of the vessel the same principles of MoC should be used to assess any changes including software updates to ensure there is a formal review process of any possible impacts it may have on the FMEA, and to impose sufficient testing ensuring the redundancy concept has not been breached.

The MoC process should be in place prior to finalizing the redundancy concept for the vessel and any changes to the redundancy concept should be subjected to the MOC process.

Critically, the integrity of the MOC process should be maintained, communicated and used effectively and it is essential that all stakeholders should have ownership in the process.

MTS DP Vessel Design Philosophy Guidelines - Section 8 Management of Change in Design (MoC):

8.1.3 Any changes to the redundancy concept should be subjected to the MOC process.

8.1.4 While changes to the redundancy concept are relatively rare it is critical that they are subjected to the MOC process as when they do occur, they can have a broad effect on vessel design.

For example:

- *Changes to the vessel industrial mission.*
- *Changes to the desired post failure capability of the vessel that changes the redundancy split say from a two-way split to a four-way split (to reduce the impact of the worst case failure).*

MoC should identify all the design changes required so that the vessel's revised design will comply with the existing or new redundancy concept.

Changes in the design that violate the redundancy concept are more common. Diligent application of the MOC process could aid in avoiding such violations.

Configuration changes to DP control systems and other equipment with software (e.g. automatic power management systems) are examples of failure to apply the MOC process.

MTS DP Vessel Design Philosophy Guidelines offer sone examples of management of change

- *Vessel moves to a new work location where a different setup is required for the acoustic position references to accommodate SIMOPS with several vessels (Wide band). Failure to control the change in working location under the MOC process could result in degraded position reference status in that location.*
- *A drilling vessel was originally equipped with two DGNSS. Modifications were made to add several more DGNSS without understanding the consequence of relying so heavily on the DGNSS as a reference to the detriment of the hydro acoustic references.*
- *To solve an unrelated reliability problem, a thruster drive manufacture adds an under- voltage trip to a thruster variable speed drive without fully understanding the consequences for the redundancy concept. This modification removed the drive's voltage dip ride through capability leading to multiple loss of thrusters when short circuit fault occurred in the power distribution system.*
- *An ESD system was fitted to a MODU without a systems engineering approach resulting in a design which introduced single point failures. A blackout occurred when the ESD system failed.*

- *Operational impact of working in shallower water depth not understood and appropriate barriers (equipment and procedures) not implemented.*

The MSF's Guidelines for Offshore Marine Operations explains that a management of change (MOC) process should be in place for all tasks.

4.2.4 ***Activity Specific Operating Guidelines (ASOG)***.

> *The ASOG contains information pertinent to the vessel's station-keeping ability, taken from operational procedures that were developed to execute the industrial mission.* **Any changes to procedures, should be assessed** *to determine whether they may also affect the ASOG and so avoid conflicting requirements. The ASOG may be modified whilst on location, subject to the full agreement of the master, and in strict accordance with the Company's Management of Change procedure.*

Experience has shown that major incidents have occurred when changes have been made to procedures, equipment, activity, approved practice, organisational structure, or personnel without proper evaluation of the potential impact of those changes. Failure to identify and manage significant change may compromise safe and efficient operations. Operational changes of all kinds may pose a hazard and increase risk exposure, requiring a reassessment of control measures to maintain acceptable levels of safety, to prevent equipment damage, and to prevent or limit environmental and health impacts.

Management of Change (MoC) is the process by which potential changes, both permanent and temporary, are analysed, their likely effects reviewed, consequences mitigated, and their implementation executed, tested and communicated. Effective MoC is essential to ensure that hazards and risk arising from change are dealt with properly.

IMCA has developed IMCA HSSE 001 August 2020, covering how to manage operations which deviate from the original execution plan in a systematic and effective way, and providing assistance for members in the requirements for the application of a formal MoC process.

Each owner/organisation will adopt their own MoC as part of their HSE quality process. There are many examples available via the internet, on the following page is a typical MoC process.

Note that some changes may require many documents to be changed such as FMEA, DP operations manuals, ASOG etc. Some may even require class approval. In reality cost will be a big driver in the decision making, but the reason for change may mean that a change MUST be implemented to solve a serious underlying fault.

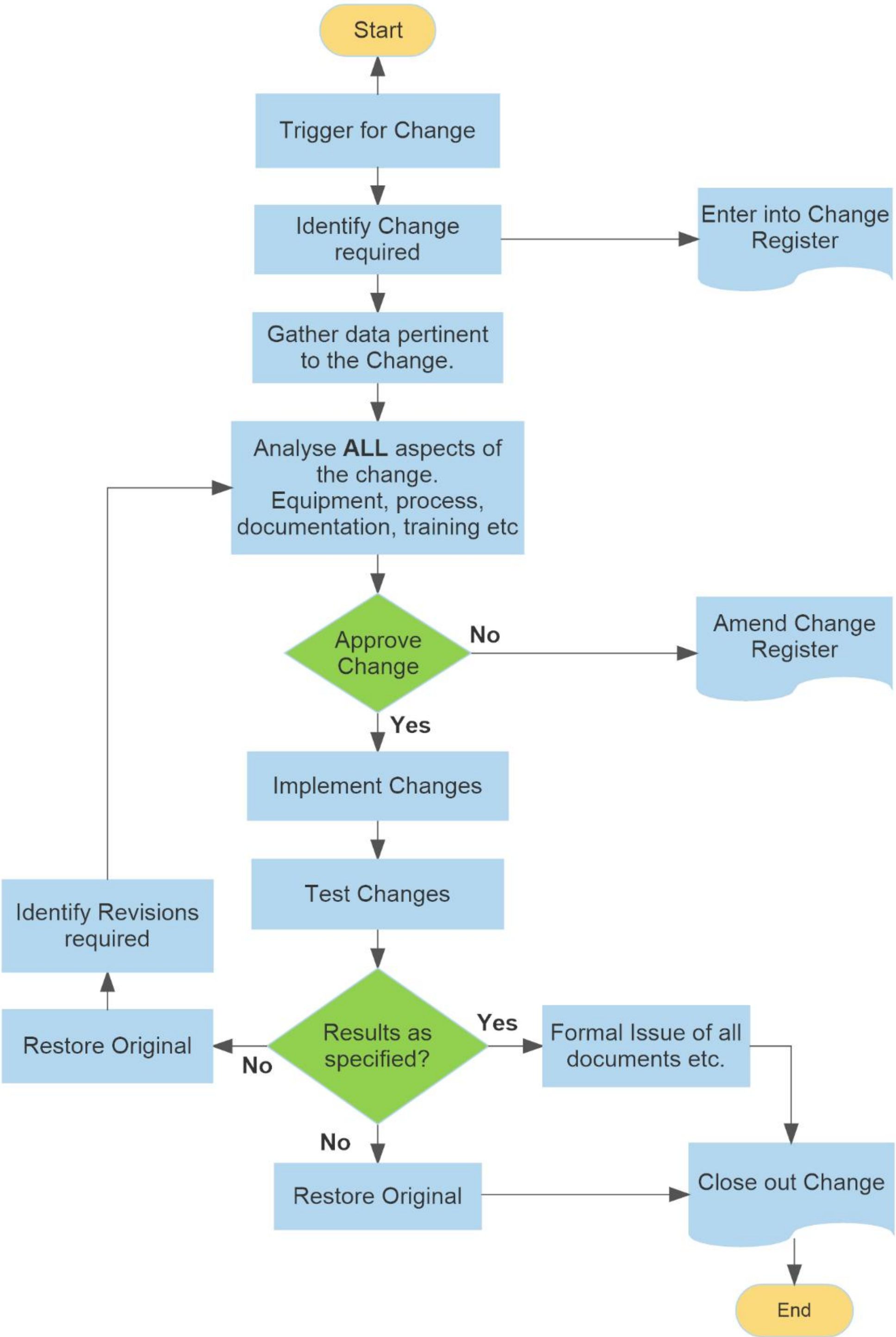


FIGURE 5 - TYPICAL MANAGEMENT OF CHANGE PROCESS

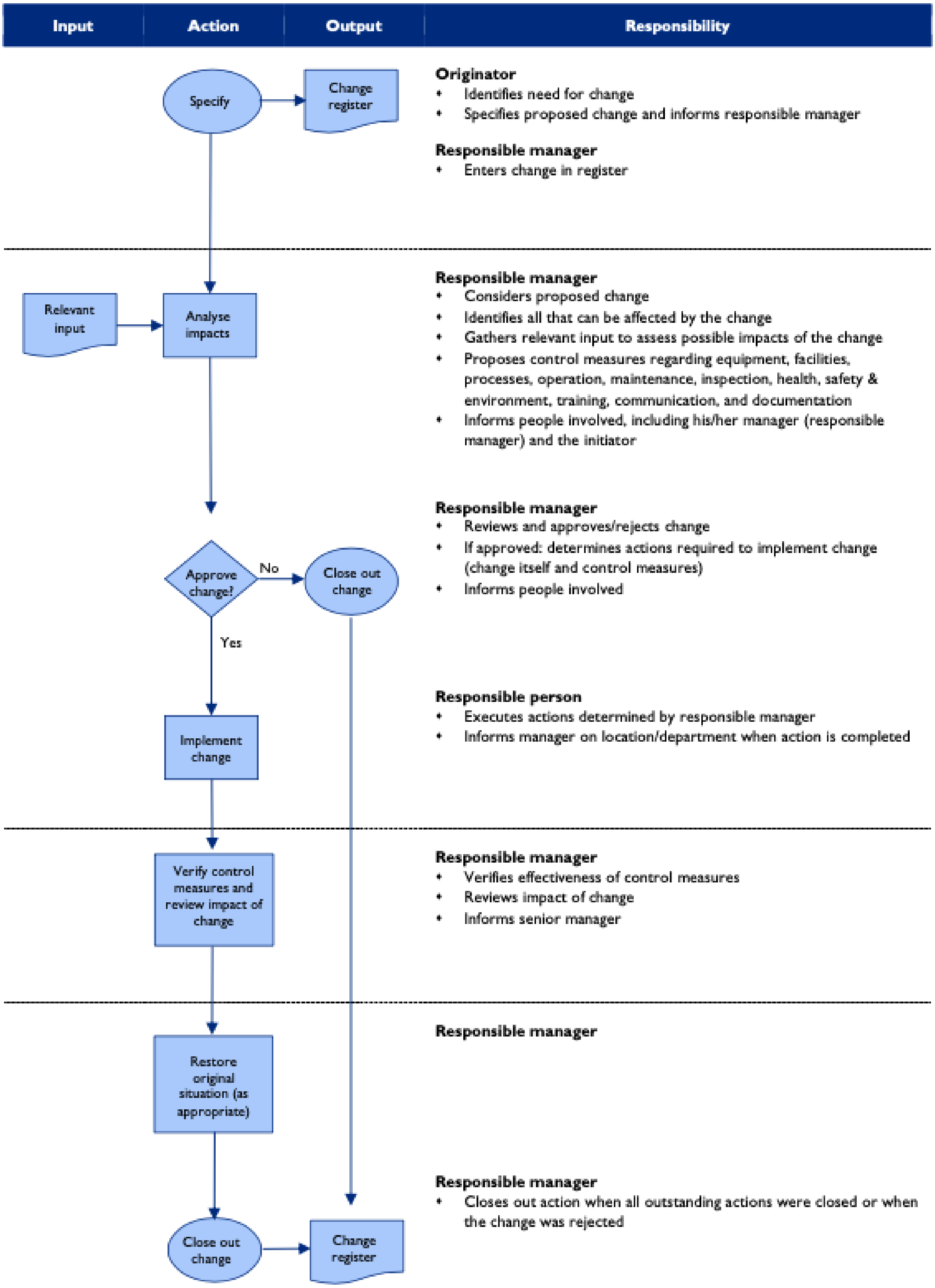


FIGURE 6 IMCA GUIDELINES FOR MANAGEMENT OF CHANGE IMCA HSSE 001 AUGUST 2020

LESSONS LEARNED THROUGH STATION KEEPING EVENTS.

DP station keeping event bulletins are available online free of charge. IMCA state that "*DP station keeping event bulletins enhance the traditional reporting and analysis of dynamic positioning station keeping events and incidents. They ensure that the industry is provided with prompt feedback, including anonymous factual case studies of events reported to IMCA.*"

The critical notion is that these are read, discussed on board, **APPLIED ONBOARD YOUR VESSEL,** and that appropriate management of change procedures are followed as per your company SMS so that that you are SURE that these incidents cannot happen to you.

See section *Lessons learned from DP Station Keeping Events*

Note that often the Station Keeping events are a bit 'light' on details, however it is a useful exercise to review them identifying details that might have caused/contributed, or might have been a way to avoid the incident etc.

Regardless of their publication fire wall IMCA encourage all, including non-members to contribute to their DP station keeping events and incidents so that lessons learnt can be used to raise the standards of safe and efficient operations throughout the industry.

The submission process involves completing a form and providing detailed information regarding the incident and casual factors and supplementary items such as sketches and actions taken.

Information gathered through this process may periodically be used in IMCA's DP Bulletins.

A DP incident is a major system failure, environmental or human factor which has resulted in loss of DP capability.

A DP undesired event is a system failure, environmental or human factor which has caused a loss of redundancy and/or compromised DP capability.

A DP observation is an event that has not resulted in a loss of redundancy or compromised DP operational capability but is still deemed worthy of sharing.

PRACTICAL ONBOARD EXERCISE

Access the Station Keeping Event Reporting Form here:- https://www.imca-int.com/resources/technical-library/dp-station-keeping-reporting/?pdf and familiarise yourself with the reporting requirements.

ABOVE AND BEYOND

MTS offer guidance on conducting effective and comprehensive DP incident investigations (2021). This TECHOP provides provide a structured approach to conducting comprehensive DP incident investigations and generating LFIs while facilitating standardization and consistency. It is designed as a **proactive measure** and suggests that "Learnings From Incidents" (LFIs) generated could be used proactively to reduce the potential for repeat incidents. This is compatible with the general principals of the IMS code and with CPD. It uses the 'fish-bone' structure of investigating to organise inputs and uses the sub-headings of design, operations, process, people to guide the investigation. The Techop also offers a completed example of a DP incident investigation which is worth a read.

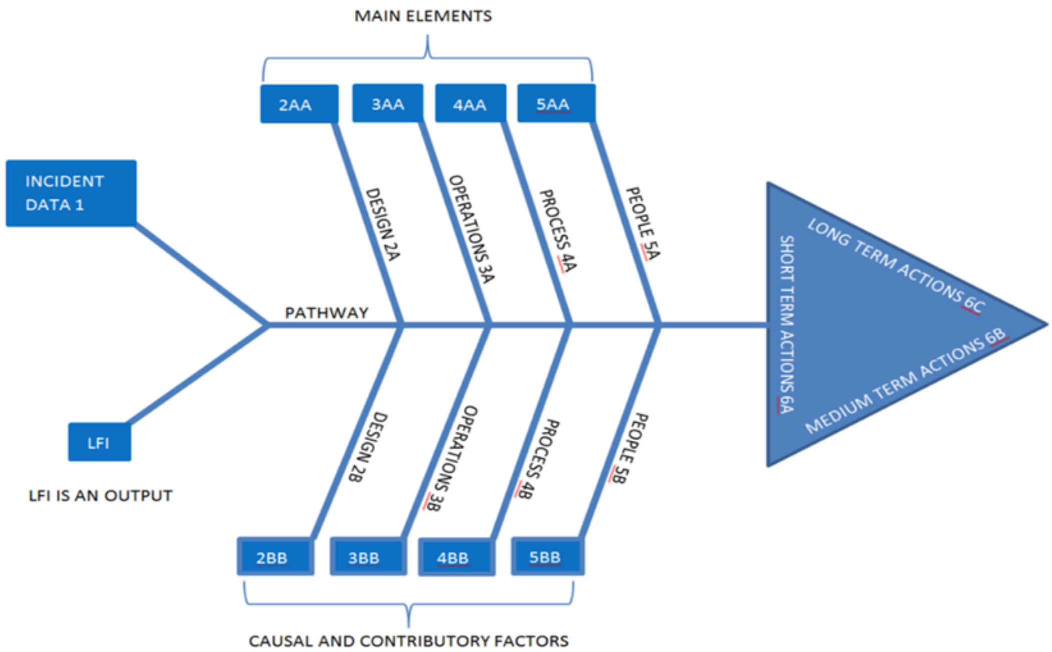


FIGURE 7 - TECHOP (G-04 - REV1 - JAN21) CONDUCTING EFFECTIVE AND COMPREHENSIVE DP INCIDENT INVESTIGATIONS

It is critical that you visit IMCAs web site and access the latest DP event bulletins. Here is a summary starting at 2021 and complete at the date of issue of this document.

2021	
DP Event Bulletin	ITEMS
01/21 – March 2021	Human Factor caused a DP Incident
	Human Factor caused a DP Undesired Event
	DP2 Cargo Vessel DP Incident
	Drill scenario - Loss of seawater cooling pump redundancy
02/21 – June 2021	Computer Error Caused a DP Incident
	Human Factor Caused a DP Undesired Event
	DP2 Service Operations Vessel (SOV) DP Incident
	DP Emergency Drill Scenario
03/21 – August 2021	Worn Components Create Unwanted Thrust
	Environment Causes DP Incident
	DP2 Supply Vessel DP Incident
	DP Emergency Drill Scenario
	News In Brief
04/21 – December 2021	Action Error - Was an ASOG in Place?
	Swift action saved stress - Know your vessel
	Consequences of Decisions - Heading Change left too late
	Configuration - PRS's Hidden Common Failure
	DP Emergency Drill Scenario
	News in Brief

2022	
DP Event Bulletin	ITEMS
01/22 – April 2022	Case Study – Masking of PRSs – SIMOPS
	Case Study – Force off Position
	Case Study – Closed Bus Common Cause
	Solitons – Be Mindful
	DP Drill Scenario
	News in Brief
02/22 – August 2022	Case Study – Maintenance – Not a Good Idea During DP Ops
	Case Study – Importance of Units
	Case Study – Consequences of Not Following ASOG
	Relative PRS – A Reflection
	DP Drill Scenario
	News in Brief

2022	
DP Event Bulletin	ITEMS
01/23 – January 2023	Case Study – Closed Bus – Knowing the Risks
	Case Study – Vessel Degraded Capability
	Case Study – Open Bus Saved the Day
	Case Study – Closed Bus Ruined the Day
	DP Drill Scenario
	News in Brief

PRACTICAL ONBOARD EXERCISE

It is critical that you visit IMCAs web site and access the latest DP event bulletins.

DP EMERGENCY DRILLS AND SCENARIOS

IMCA have created DP emergency drill scenarios that are freely available on their website here. The are designed to assist DP vessel management and DPOs / engineers and ETOs to conduct DP drills onboard.

Each suggested drill scenario follows the same proforma and mariners are encouraged to learn from this and, with practice, create their own.

- Objective
- Method
- Discussion points (pre-exercise)
- Observations during exercise
- Actual results witnessed
- Discussion points (post-exercise)
- Conclusion

DP DRILL PRACTICAL ONBOARD EXERCISE

Visit the IMCA website and quickly skim read all their published drill scenarios. Choose the one that is most applicable to you, your level of experience, and your role onboard. Ask your immediate line manger if this drill can be replicated as part of the vessels drill matrix.

If not, run the drill by yourself, or with a college AS A TABLETOP EXERCISE giving each stage careful consideration.

DRILL SCENARIO EXAMPLE[1]

Objective: *To familiarise all vessel crew with what actions are required in order to recover the vessel into controllable condition following a thruster failure to full thrust*
Method: *This test can be undertaken when the vessel is in a safe open space with no risk of excessive position excursion causing an unsafe condition. If the vessel has CPP Main thrusters carry out using CPP.*

1. *Settle vessel on auto DP*
2. *A second person to take the most powerful thruster into manual control*
3. *Ramp that thruster to 100% in a direction perpendicular (if azimuth thruster) to the Auto DP thrust. If carrying out for CPP, put CPP thrust in the opposite direction*

Observe effects Observations During Drill – Consider:

- *Does the DP Control system compensate?*
- *Is there an initial excursion?*
- *What action would the DPO take?*
- *Is the degree of participation and diligence of Key DP Personnel as expected?*

Discussion Points – Consider:

- *How are the thrusters placed on the vessel, where single skeg thrusters are fitted, what are the implications of this failing to full thrust - this failure may still be within the FMEA Stated WCFDI?*
- *Can a forward retractable azimuth thruster, counteract two bow tunnel thrusters?*
- *Powerful stern CPP Propellors - if one failed to full thrust is position compromised?*
- *Where Rudders are used for position control, consider if the prop fails to full thrust and the rudder still follows a DP command*

Human Factors – Consider:

- *What should the response of the DPO?*
- *What would be the worst-case scenario?*
- *Discuss the alternative actions/reactions that may occur in response to a similar scenario. Are there multiple paths to a successful resolution or is there a preferred solution? Why?*

[1] Taken from IMCA

Review of DPO and other key DP personnel reaction

- *What potential gaps in the existing DP Familiarisation program have been highlighted as a result of the exercise?*
- *What changes/revisions should be considered for the training and familiarisation procedures?*
- *Review the applicable checklists (ASOG CAM/TAM/D operations Manual/bridge and engine room checklists/*
- *FMEA/DP Annual Trials programmes/etc.)*
- *What additional necessary actions and considerations should be addressed? What potential changes should be made to make the checklists more appropriate? What additional necessary operating conditions and parameters should be considered? What potential changes should be considered to make Decision Support Tools more applicable to the vessel and her equipment?*
- *How would these changes improve/affect the vessel's capabilities and limitations?*

Conclusion: *Based on the results of the exercise and related discussions before and after, make suggestions for change including:*

- *any corrective actions deemed appropriate should be accurately detailed and managed to close out.*
- *Handling of thruster system failures in the correct manner requires knowledge of the DP vessel control, how the Up system reacts to failures and alarms and the human intervention required if necessary to ensure station keeping.*
- *awareness of the current thrust levels and directions*
- *DP system reaction to failures*
- *appropriateness of communication*
- *training requirements*

For all the Drills, it may be better to find a way to trigger the 'event' in a way that is more representative of a real DP incident, so in the above example the act of taking the thruster into manual would remove it from the DP (i.e. available would drop off) so this would indicate immediately which thruster was 'bad' ?

ROLES & RESPONSIBILITIES OF KEY DP PERSONNEL (ACCORDING TO M117)

In June 2017, the IMO released circular 738 that requested all Member States bring an IMCA document, ***IMCA M 117 Rev.2 "Training and Experience of Key DP Personnel"*** to the attention of all parties concerned. This document identifies training programmes, levels of competency and experience for the safe operation of DP vessels and will be covered in chapter two of this module.

This is the ONLY industry document that is linked to an IMO circular and as such it cannot be changed without the approval of the IMO's marine Safety Committee. The last revision was in September 2016.

We discus key features of IMCA M117 below but recommend that you download a copy to your briefcase or download the Keelson Dynamic Positioning app.

One of the most common barriers to onboard training and CPD is TIME. Note that IMCA M117, in **3.2 Operational Conditions** states:

> *Vessel owners/operators should be enabled by clients and charterers to allocate time in their DP vessels' schedules for training and drills; clients should encourage this as suitable opportunities arise. This should include drills which involve both bridge/DP control and machinery control room teams.*

Remembering that the IMO has bought this to the attention of all member states and incorporating 5.6 of the **ISM Code Resources and Personnel**

> *5.6.5. The Company should establish and maintain procedures for identifying any training which may be required in support of the SMS and ensure that such training is provided for all personnel concerned.*

we can see that it is mandatory, and certainly not unreasonable, to expect companies and their clients to provide TIME for seafarers to complete CPD and training onboard. But IMCA M117 and the ISM code put the onus in providing training and CPD onto the owner and for that reason Keelson's CPD is designed to support shipping companies provide this for their personnel. If you are an independent practitioner shouldering the time and financial burden of this CPD programme alone, we salute you and suggest that your raise this with your employer.

IMCA M117 AIMS

IMCA M117 has two aims:

> *4 Aim and Objectives*
>
> *4. 1 Aim*
>
> *The aim of these guidelines is to improve the safety and efficiency of DP operations, by defining minimum industry guidelines for:*
>
> - *training, qualification and competence levels of key DP personnel.*
> - *developing and sustaining competence through continuous professional development (CPD) for key DP personnel.*

In chapter 7 of IMCA M 117 document identifies nine key DP personnel and defines their qualification and knowledge requirements. This CPD programme is differentiated to meet the specific needs of chapter 7. That is, a master/OIM will get harder questions than a DPO and different questions to that of a chief engineer. This is because Keelson's DP CPD is also aligned in MTS PDDP 2 with its three levels of learning as discussed earlier.

Note also that chapter 10 of IMCA M 117 is devoted to Key DP Personnel Continuous Professional Development (CPD) and clearly states that the provision of CPD lies at company level:

> *CPD programmes should be an integral part of the vessel owner/operator SMS and should establish the assessment and training periods for key DP personnel and whether this is conducted onboard or ashore.*

PRACTICAL ONBOARD EXERCISE

Look at IMCA M117 chapter 7 and identify your key DP personnel role onboard your current vessel; NOTE: you will have already done this to enrol on the correct DP CPD pathway with Keelson.

Examine the qualification and knowledge requirements for your role/rank onboard. For your two Keelson DP CPD assessments (base line and improvement assessment) you will be asked questions on the FULL RANGE of knowledge requirements for your role EVERY YEAR, not just the topics selected by the Nautical Institute for annual review as summarised in **Error! Reference source not found.** of this Learning Manual.

ABOVE AND BEYOND

Compare the requirements for your role or rank on board as defined in IMCA M117 and in MTS PDDP2.

This section contains information on the following topic areas as defined by the Nautical Institute.

DP Testing & Trials
FMEA
FMEA - purpose, class & guidance requirements, class involvement, specific guidance, objectives, failure types (single, common, hidden, etc)
FMEA Proving trials - guidance, purpose, requirements, what should be demonstrated (redundancy concept, effectiveness of protective functions, stability of the system over full range of load conditions, monitoring functions, degraded and failure condition, etc.)
FMEA 5 years proving trials - purpose, requirements, guidance, what should be demonstrated, etc
DP Annual Trial
IMCA M190, purpose, class & guidance requirements, class involvement, specific guidance, objectives, IMCA DP Practitioner Accreditation Scheme
Field Arrival Trials
Guidance, purpose, requirements, what should be demonstrated
DP Networks (Move to DP System)
DP Network system - overview & the risks, guidance available
DP Network system - Operational & Failure considerations
DP Network system - Lessons learnt from DP Events DP Network system

FMEA – PURPOSE, OBJECTIVES, CLASS & GUIDANCE REQUIREMENTS, CLASS INVOLVEMENT, SPECIFIC GUIDANCE

Vessel FMEA (Failure Modes and Effects Analysis) is a systematic methodology used to identify potential failure modes and assess the risks and effects associated with them. It is a risk assessment tool that considers the vessel's DP systems and components, as well as the potential consequences of failure, to prioritize areas for improvement and minimize the risk of vessel downtime and other negative impacts. The FMEA process helps to identify design, operational, or maintenance-related issues that could lead to equipment failure, and it is used to improve safety, reliability, and efficiency in DP vessels.

IMO MSC/Circular 1580 defines an FMEA as:

> *1.2.13 Failure Modes and Effects Analysis (FMEA) means a systematic analysis of systems and sub-systems to a level of detail that identifies all potential failure modes down to the appropriate sub-system level and their consequences.*

And it requires that

> *5.1.2 For equipment classes 2 and 3, an FMEA should be carried out. This is a systematic analysis of the systems to the level of detail required to demonstrate that no single failure will cause a loss of position or heading and should verify worst-case failure design intent. This analysis should then be confirmed by FMEA proving trials. The FMEA and FMEA proving trials result should be kept on board and the FMEA should be kept updated so that it remains current*

An FMEA is a document, usually a large document, prepared by an FMEA contractor and approved by the classification society for the vessel. Without an FMEA the classification society will not allocate a vessel notation as DP class 2 or 3.

The FMEA is a means of proving the redundancy concept of the vessel to ensure safe and reliable DP operations. OCIMF (Oil Companies International Marine Forum) have produced a document Dynamic Positioning Failure Mode Effects Analysis Assurance Framework Risk-based Guidance (2020) that is useful when analysing the contents of an FMEA.

It states that FMEAs are performed to

- *Verify the redundancy design intent (RDI) of the vessel.*
- *Prove that redundant equipment groups are independent and fail-safe.*
- *Identify common points that compromise independence between redundant equipment groups.*
- *Assess common points to determine the effects of failures (both benign and aggressive) that propagate through common points, as well as the effectiveness of mitigations for unacceptable effects.*
- *Develop a proving trials program to validate the analysis.*

IMCA offer a flow chart of the Failure Modes Effects Analysis process that demonstrates how technically involved and iterative the process is. It also demonstrates the technical and commercial depth of the FMEA team required.

The FMEA, during the design phase, can be an iterative process if proposed designs are found to have flaws. Note that the FMEA produced for the offshore industry does not evaluate based on the likelihood or the severity of the faults. If any perceived fault causes a greater failure than the defined WCF, then it must be eliminated.

A simplified flow diagram is presented on the following page.

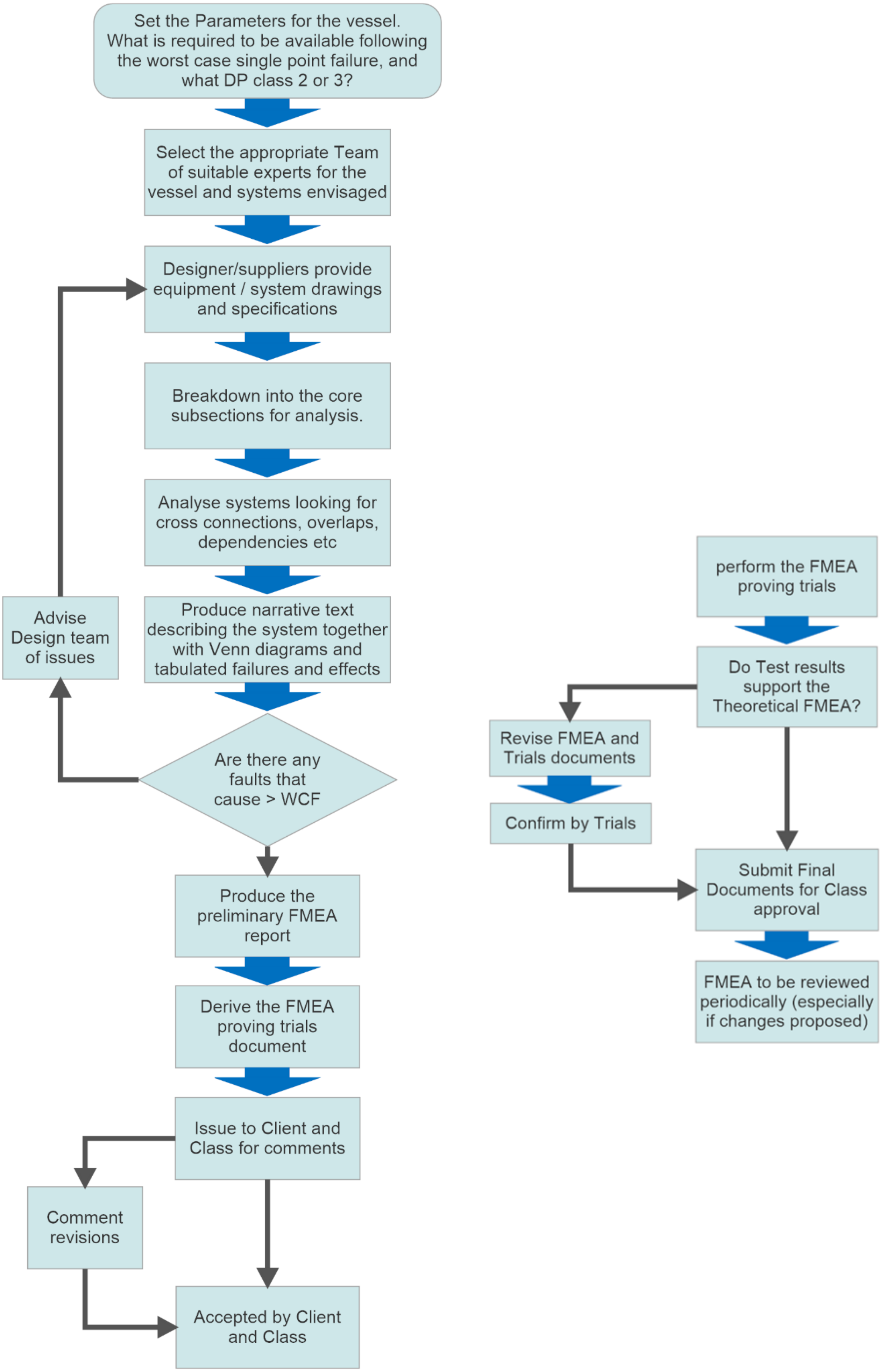


FIGURE 8 - The Basic FMEA Flow During Design and Construction and Confirming Trials

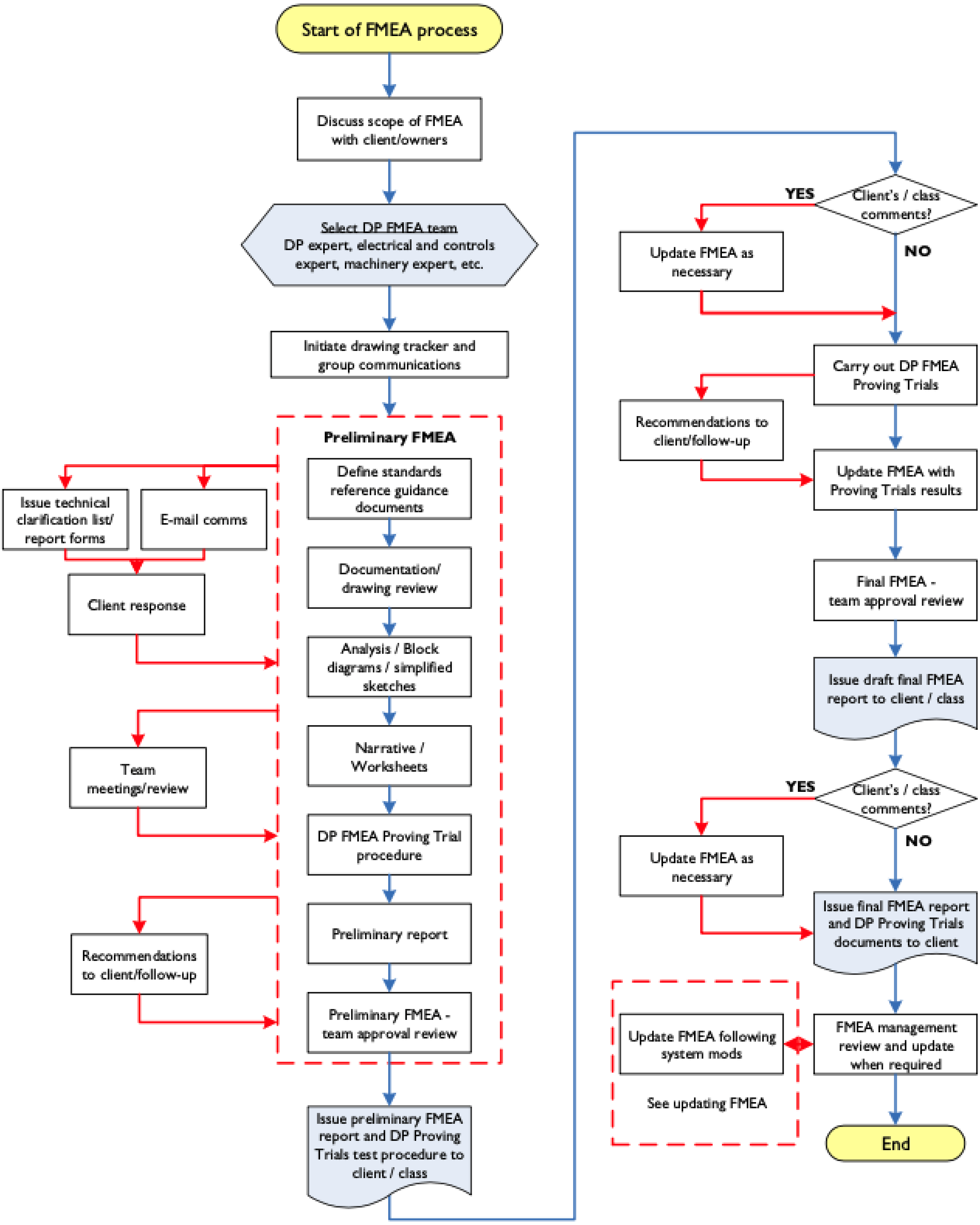


FIGURE 9 - IMCA M 166 REV. 2 - IMCA M 166 REV. 2

An FMEA is intended to be an exhaustive examination of all the systems on board the vessel that are directly or indirectly associated with the DP system function. MTS have produced a 'Gap analysis tool'. This document allows an assessment of the FMEA by asking questions based around the major systems involved with a DP vessel. By posing questions it allows the user to capture a snapshot of the FMEA. It is easy to analyse a system and to recognise for instance that there are no cross connections but then not state that fact in the FMEA. The GAP analysis asks if it is not stated was it because it was missed or just not confirmed. Because it covers the most complex vessels it can seem a little heavyweight but for any FMEA it is a useful aide memoire if nothing else.

The various GAP analysis tools are available on the MTS website by clicking **here**

Think about the difference between the redundancy upon which the DP concept is based and the redundancy within some systems that contributes to availability.

A typical example is a duty/standby FW pump arrangement for a single thruster. If a pump has failed the other allows the thruster to carry on, but it still has not reduced the overall redundancy. Why? Because there are still single failures that can stop the thruster.

On sea chests we often have dual strainers for exactly the same reason.

Think about the systems on your vessel what is critical to supporting the redundancy concept.

IMO MSC/Circular 1580 defines redundancy as

> *1.2.21 Redundancy means the ability of a component or system to maintain or restore its function when a single failure has occurred. Redundancy can be achieved, for instance, by the installation of multiple components, systems or alternative means of performing a function.*

This is normally achieved by placing more than one of any component onboard, for example two different types of position reference system. Or by or setting up integrated components (systems) up as complexly separate groups.

Consider the two completely separate redundancy groups in the thruster diagram below.

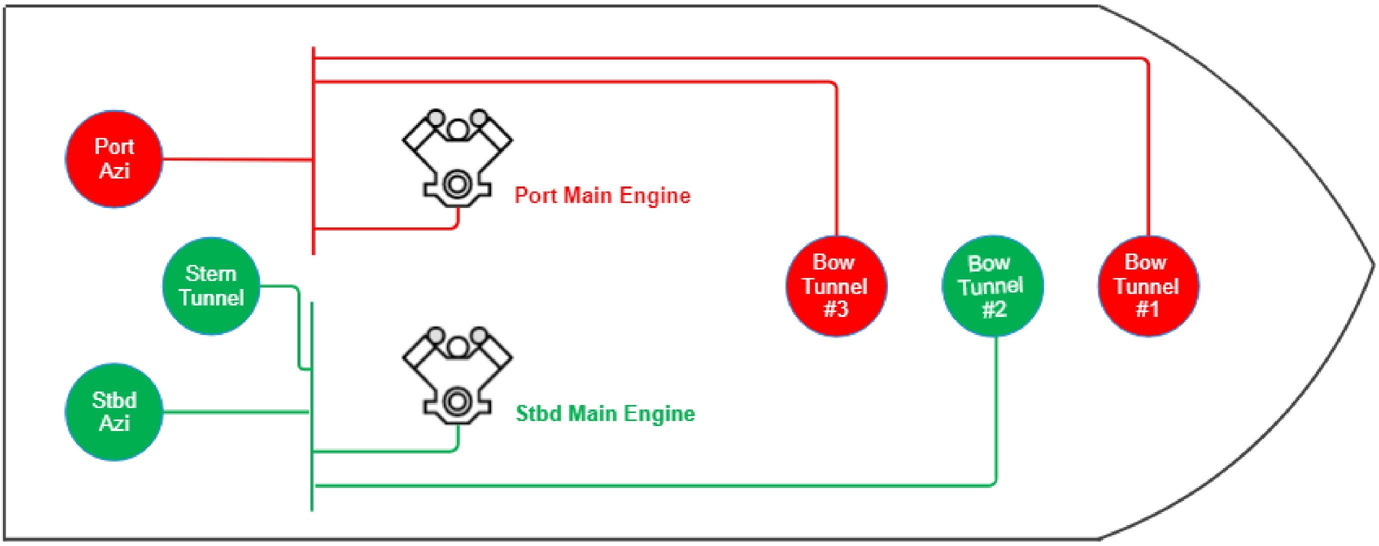


FIGURE 10 - TYPICAL DP2 VESSEL LAYOUT

A ***single failure*** in the context of the redundancy definition means a fault that could lead to a **worst case failure.** IMO MSC/Circular 1580 defines a worst case failure as:

> *1.2.25 Worst-Case Failure (WCF) means the identified single fault in the DP system resulting in maximum detrimental effect on DP capability as determined through the FMEA.*

The ***detrimental effect*** referred to here is the reduction in power / thrust due to the fault but which the remaining equipment is still able to maintain position and heading.

IMO MSC/Circular 1580 has designated three equipment classes. Each equipment class is defined by the level of redundancy (the installation of multiple components) needed to protect the DP system worst case failure (loss of a loss of position and/or heading) and it defines what is considered a single fault in each case.

> *.1 For equipment class 1, a loss of position and/or heading may occur in the event of a single fault.* (i.e. there is no redundancy)

> *.2 For equipment class 2, a loss of position and/or heading will not occur in the event of a single fault in any active component or system. Common static components may be accepted in systems which will not immediately affect position keeping capabilities upon failure (e.g. ventilation and seawater systems not directly cooling running machinery). Normally such static components will not be considered to fail where adequate protection from damage is demonstrated to the satisfaction of the Administration. Single failure criteria include, but are not limited to:*

>> *.1 any active component or system (generators, thrusters, switchboards, communication networks, remote-controlled valves, etc.); and*

.2 any normally static component (cables, pipes, manual valves, etc.) that may immediately affect position keeping capabilities upon failure or is not properly documented with respect to protection.

.3 For equipment class 3, a loss of position and/or heading will not occur in the event of a single fault or failure. A single failure includes:

.1 items listed above for class 2, and any normally static component assumed to fail.

.2 all components in any one watertight compartment, from fire or flooding; and

.3 all components in any one fire sub-division, from fire or flooding.

NOTE: the difference between equipment class 2 and equipment class 3 DP vessels is that ANY static component must not fail (rather than only those static components that *may immediately affect position keeping capabilities*) AND the separation of components by fire and flood protection. It is a common misnomer that DP vessels need more components or systems, they don't; they just need to protect them more.

Case Study – Vessel Degraded Capability

FMEA FAILURE TYPES (SINGLE, COMMON, HIDDEN, ETC)

IMO MSC/Circular 1580 defines a failure as:

1.2.12 Failure means an occurrence in a component or system that causes one or both of the following effects:

.1 loss of component or system function; and/or

.2 deterioration of functional capability to such an extent that the safety of the vessel, personnel or environment protection is significantly reduced.

And redundancy as

*1.2.21 Redundancy means the ability of a component or system to maintain or restore its function when a **single failure** has occurred. Redundancy can be achieved, for instance, by the installation of multiple components, systems or alternative means of performing a function.*

MTS DP Vessel Design Philosophy Guidelines gives some practical examples of possible failures and their consequences.

3.2.6 Failure analysis vocabulary

- *Failure modes: The mode of failure describes the way in which a component or system fails. For example, a diesel engine may fail to over speeding, hunting rpm or stop. The cause of this failure mode could be a clogged filter.*
- *Failure effects: The effects of a component or system failure can be defined at several levels in the DP system architecture including the local effect and the end effect:*
    - *Local effects: The local effect is the effect on the system at the failure point itself. Using the same example of a faulty cable, the local effect of a short circuit would be high current in the cable followed by operation of the upstream overcurrent protection to isolate the fault.*
    - *End effects: The end effect is the effect at the level at which the top event is defined (Typically loss of position and / or heading) Using the cable example above, top event of the cable short circuit may be a voltage dip that causes all thruster drives to malfunction leading to loss of position and / or heading. The effect of the open circuit may be less severe. Typically, loss of one generator or a thruster becomes unavailable. In the case of the ground fault the end effect may be an alarm with no greater effect on position or heading.*

Note that in the last paragraph if the 'End Effect' is a loss of position or heading then the outcome of that fault is not acceptable and must be mitigated so it will not result in anything worse than the defined 'Worst Case Failure'.

In a typical FMECA (Failure Modes, Effects and Criticality Analysis) failures are analysed and categorised according to how serious their consequences are (Criticality), how frequently they could occur (Likelihood), and how easily they can be detected (or even if they can be detected).

At present the industry requires an FMEA and does not discriminate and assumes all faults can occur and the system cannot subsequently degrade beyond the defined worst case failure.

SINGLE FAILURE

We know the Vessel will be assigned its DP Classification based on the effect of a single failure (or single fault).

> *.1 **For equipment class 1**, a loss of position and/or heading may occur in the event of a single fault.*
>
> *.2 **For equipment class 2**, a loss of position and/or heading will **not** occur in the event of a single fault in any **active** component or system. Common static components may be accepted in systems which will not immediately affect position keeping capabilities upon failure (e.g. ventilation and seawater systems not directly cooling running machinery). Normally such static components will not be considered to fail where adequate protection from damage is demonstrated to the satisfaction of the Administration. **Single failure criteria include**, but are not limited to:*
>
> > *.1 any **active** component or system (generators, thrusters, switchboards, communication networks, remote-controlled valves, etc.); and*
> >
> > *.2 any **normally static component** (cables, pipes, manual valves, etc.) **that may immediately affect position** keeping capabilities upon failure or is not properly documented with respect to protection.*
>
> *.3 **For equipment class 3**, a loss of position and/or heading will **not** occur in the event of a single fault or failure. A single failure includes:*
>
> > *.1 items listed above for class 2, and any normally static component assumed to fail;*
> >
> > *.2 all components in any **one watertight compartment**, from fire or flooding; and*
> >
> > *.3 all components in any **one fire sub-division**, from fire or flooding (for cables, see also paragraph 3.5.1).*

The vessel's worse case failure (WCF) used in the consequence analysis (FMEA) is determined using this equipment class single failure criteria. See section Redundancy Concepts for more information on worse case failure (WCF).

HIDDEN FAILURE

A hidden failure is defined by IMO MSC/Circular 1580 as:

> *1.2.15 Hidden failure means a failure that is not immediately evident to operations or maintenance personnel and has the potential for failure of equipment to perform an on-demand function, such as protective functions in power plants and switchboards, standby equipment, backup power supplies or lack of capacity or performance.*

The MTS DP Vessel Design Philosophy Guidelines state that *Hidden failures have the potential to defeat the redundancy design intent.* They explain that failure of dormant or on demand functions such as standby redundancy and protection systems are examples of potential hidden failures. For example, all interlocks are potential hidden failures. Critical interlocks should be tested non-destructively and periodically to confirm their effectiveness.

COMMON FAILURE

Common connections between systems, intended to provide redundancy, create the paths by which a fault in one redundant system may affect another independent system.

MTS DP Vessel Design Philosophy Guidelines remind us that:

> *In any system based on redundant elements there can be internal and external **common cause failure** that are capable of defeating the redundancy design intent.*

and that

> ***Independence** between equipment groups intended to provide redundancy ensures they are not subject to a common cause of failure*

Conversely "dependencies" is the term used to describe the relationship between one component and another. Dependencies between redundant equipment groups may cause them to be vulnerable to a common cause of failure.

It is really important that you understand what an FMEA is and that you understand exactly what your vessel's FMEA is telling you, and how it supports your role onboard a DP vessel. MTS DP Operations Guidance states:

> *4.3.10 Key DP personnel, including the vessel master, DPOs, engineers and electricians should have a detailed knowledge of the DP FMEA and should use the information provided to be fully informed about the capabilities and limitations of the vessel's DP system.*

PRACTICAL ONBOARD EXERCISE

Find your vessel's FMEA.

Is it colour coded?

What failure modes does it document and what are the consequences of these failures?

ABOVE AND BEYOND

It is useful to take a step back at this stage an consider the end goal: *the delivery of incident free DP operation.* This is a concept that MTS define as ***predictability***.

MTS's DP Vessel Design Philosophy Guidelines provide us with an *Integrated Thinking* model that looks incredibly complicated at first glance but which, when explored it will improve your understanding of key DP concepts.

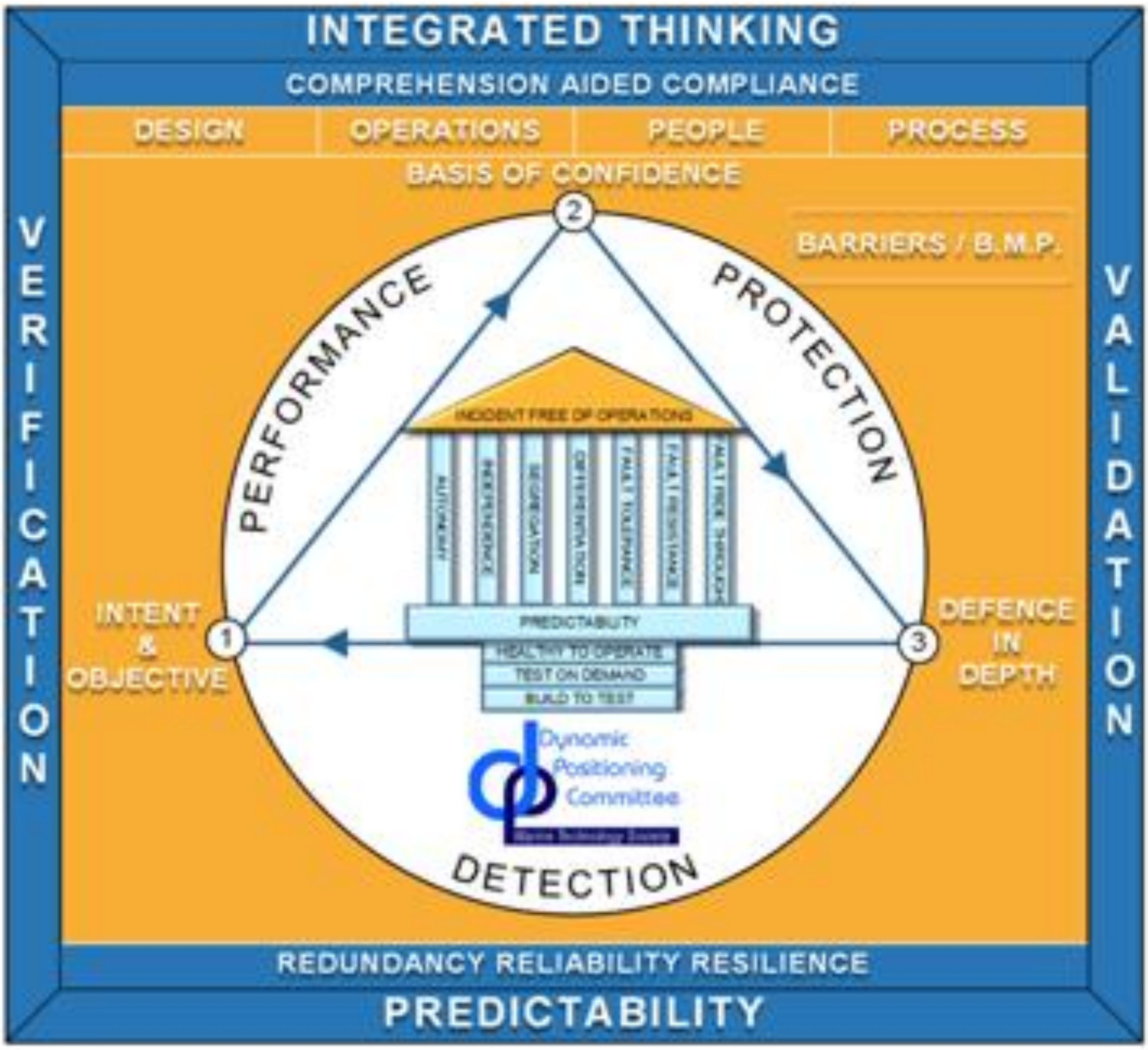


FIGURE 11 - MTS THINKING MODEL

MTS state that there are three essential attributes of any fault tolerant system based on redundancy

***Performance**: Elements of the system intended to provide redundancy must have equivalent performance in all redundancy groups.*

***Protection**: In any system based on redundant elements there can be internal and external common cause failure that are capable of defeating the redundancy design intent. Protection systems are required to limit the end effects of failures to the redundant group in which the failure occurred or protect the overall system (all redundant groups) from such influences.*

***Detection**: Fault tolerant systems based on redundancy are only fully fault tolerant while all redundant groups and the control and protection systems on which they depend are fully operational.*

Consider the role of performance, protections, and detection in the diagram below taken from MTS's DP Vessel Design Philosophy Guidelines

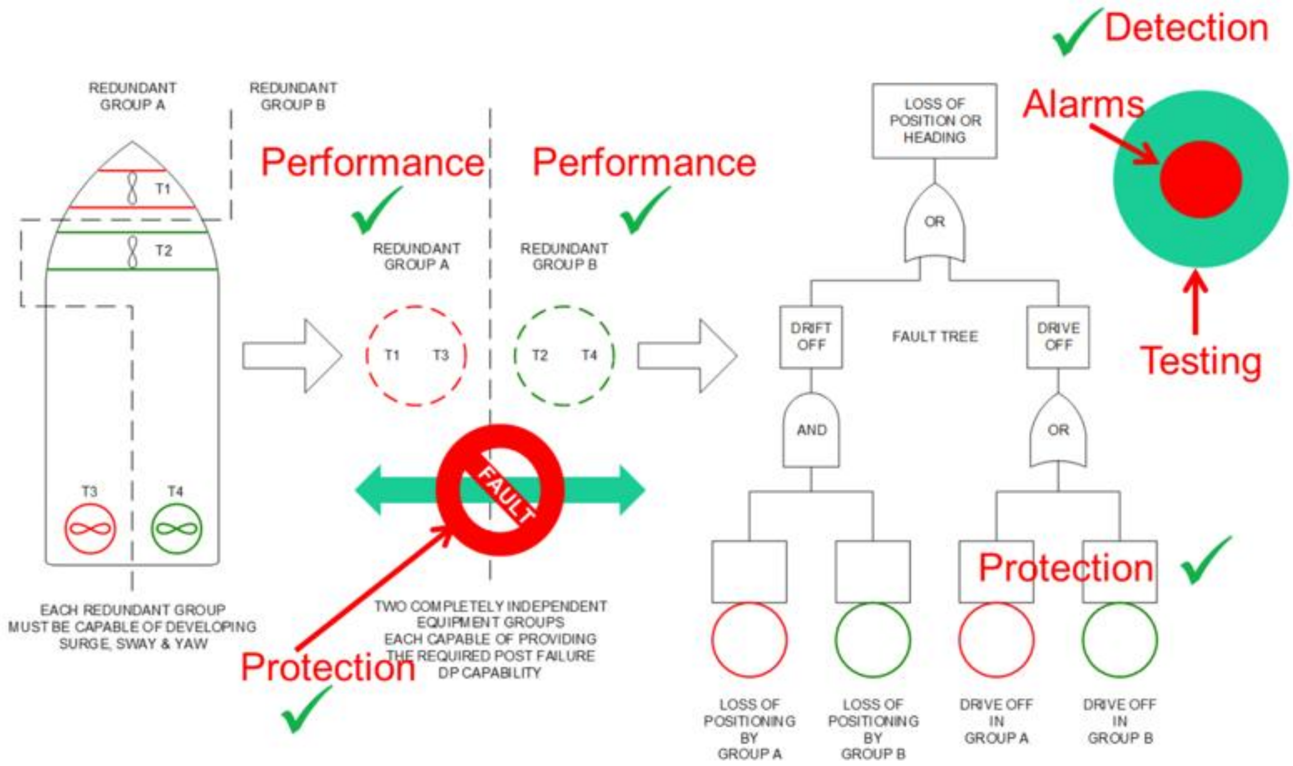


FIGURE 12 - MTS COMBINED ICONOGRAPHY INTEGRATED THINKING

- Redundancy concept,
- Effectiveness of protective functions,
- Stability of the system over full range of load conditions,
- Monitoring functions,
- Degraded and failure condition, etc.

DP FMEA proving trials are intended to establish the level of redundancy and fault tolerance provided by the DP system and confirm the analysis in the FMEA. The DP system of DP class 2 and DP class 3 vessels must be single fault tolerant in respect of defined failure criteria. At DP FMEA proving trials a large number of tests and failure simulations are carried out to prove that equipment and systems intended to provide redundancy have the necessary performance, protective functions and monitoring systems to ensure the integrity of the DP redundancy concept.

IMO MSC/Circular 1580 defines FMEA proving trials as *means the test program for verifying the FMEA.*

In Section 5 Surveys, Testing and Dynamic Positioning Verification Acceptance Document (DPVAD) it states that

> *5.1.2 For equipment classes 2 and 3, an FMEA should be carried out. This is a systematic analysis of the systems to the level of detail required to demonstrate that no single failure will cause a loss of position or heading and should verify worst-case failure design intent.* ***This analysis should then be confirmed by FMEA proving trials. The FMEA and FMEA proving trials result should be kept on board and the FMEA should be kept updated so that it remains current.***

MTS DP Operations Guidance - Part 1 states that DP FMEA proving trails are to be:

> *conducted to prove initial DP FMEA and at other times to prove modifications and additions to the DP system. DP FMEA Proving Trials should be repeated every five years. Findings and recommendations to be addressed in accordance with their criticality. All records to be kept on board.*

IMCA M103 goes further and states that FMEA proving trials are:

additional to commissioning and owner acceptance trials

And that proving trials should be:

> *properly documented and the results made available to operators, owners, charterers, surveyors and responsible authorities, to remove the necessity of repetition of design related trials during the vessel's working life and as input into operational manuals and vessel familiarisation procedures.*

In section 2.4 DP System Trials, Tests and Checks IMCA M103 states that DP FMEA proving trails should confirm the worst case failure design intent (WCFDI) and worst case failure (WCF) see section Redundancy Concepts , and should also

- *identify the subsystems and equipment and modes of operation;*
- *identify all potential failure modes and their causes;*
- *identify single point failures;*
- *identify potential hidden failures;*
- *identify potential configuration errors;*
- *evaluate the effects on the DP system of each failure mode.*

IMCA M 247 identifies over forty (40) potential failure modes and other considerations associated with DP systems and sub systems. It is impossible to discuss every potential failure mode presented in this document, and as IMCA state themselves this list is not exhaustive. However, we suggest that you cross reference your vessels FMEA with the section 4 *Identification of Failure Modes* as an **above and beyond** task.

However, we do highlight here two sections, one engineering based -Lubricating oil, and one deck (DPO) based - Computers and Consoles to illustrate how a Failure Modes Effect Analysis will test the effectiveness of protective functions, the stability of the system over full range of load conditions, monitoring functions, and degraded and failure conditions (as required by the Nautical Institute CPD revalidation criteria "Annex K").

4.1.2 Lubricating Oil

The FMEA should look for common failures, which affect not only running engines but also those on standby. The alternator bearing system should be included. The engine may also have subsidiary lubricating oil (LO) systems such as those for rocker arms. In the vast majority of cases, failure of an LO system is limited to one engine.

LO storage and transfer facilities may be assessed, but the FMEA of this system normally starts at the sump. The sump level alarms and frequency of checking sump level should be identified. If there are online purification facilities, the interlocks and procedures to prevent pumping LO from one sump to another, which could lead to a low LO pressure shutdown or potentially a crankcase explosion, should be analysed.

The use of pre-LO pumps, engine driven pumps and electrical main and standby pumps should be analysed. In particular, the pre-LO pump power supplies, pre-LO pump failure warnings and engine start logic should be reviewed to ensure that a standby engine or set of engines is not inhibited from starting when required by the PMS.

There should be a clear understanding of the levels of LO pressure and temperature for warnings, starting standby engines, controlled shutdown and immediate stop. Such functions may be performed by one system or several different systems, e.g. engine management system, PMS, load sharing/ synchronising system, network, etc. Which system initiates breaker opening and closure should be determined. The effects of oil mist detector alarms or failures should be reviewed to determine if there are any conflicts between engine safety and the requirements of DP. The design of the LO alarm system on alternators should be treated as seriously as that on a diesel engine, as alternator bearing failure leading to serious alternator misalignment could cause a generator short circuit, catastrophic failure and significant power instability.

The alarms available for filter differential pressure should be confirmed. The common failure of automatically cleaned filters should be considered.

and

4.7.2 Computers and Consoles

All the DP system vendors provide a range of products as well as a large number of options to suit the widely varying activities of the DP vessel fleet. The specification stage of design needs to focus on ensuring that all the required functions are provided and also that unnecessary hardware and software is not installed. The layout of consoles, computers and reference sensors also needs to be confirmed.

For common operator system consoles, it has been common practice to recommend soft shutdown of the console before carrying out power failure tests. In such situations, there is usually a bumpless transfer to the back-up system when power is failed. However, during UPS trials, a different failure mode has been reported when UPS batteries expire unexpectedly, and half the DP system crashed. In this case, there was loss of control over all thrusters and DP control on the backup system had to be forced manually.

Considerable attention may need to be paid to the design of 'fire backup' switches and other such changeovers between main and backup DP systems, and also between various DP systems and manual thruster control. Normally, it will be necessary to perform an FMEA of the changeover logic to be satisfied that all requirements are met in relation to open circuit, short circuit, loss of power, alarms for hidden failure or misalignment of switches. Similar attention should be paid to bridge engine controls and emergency stops.

More recently, classification societies have made specific requirements in relation to the failure modes of e-stop functions and the provision of wire break detection.

Although the DP system is by design a redundant system, a separate independent joystick system (IJS) is required for DP equipment class 2 and 3. IJSs require failure consideration and the FMEA should detail a description of the system and its redundancy concept. Detail of sensors interfaced to the system and the independence of the system requires analysis and testing during FMEA proving trials.

PRACTICAL ONBOARD EXERCISE

Find your vessel's FMEA. What failure modes does it document and what are the consequences of these failures?

Consider and discuss the two examples above in what way do the various 'failures' impact the redundancy concept? What are the possible performance, protection and detections functions available to the crew?

ABOVE AND BEYOND

Dynamic Positioning Failure Mode Effects Analysis Assurance Framework Risk-based Guidance (2020)

IMCA M 166 – Guidance on failure modes and effects analyses (FMEAs).

IMCA M 247 November 2018 Guidance to Identify DP System Components and their Failure Modes

IMCA M190, PURPOSE, CLASS & GUIDANCE REQUIREMENTS, CLASS INVOLVEMENT, SPECIFIC GUIDANCE, OBJECTIVES,

IMO MSC/Circular 1580, section 5.1 Surveys and testing states that:

> *5.1.1.3 an annual survey should be carried out within three months before or after each anniversary date of the Dynamic Positioning Verification Acceptance Document. The annual survey should ensure that the DP system has been maintained in accordance with applicable parts of the Guidelines and is in good working order. The annual test of all important systems and components should be carried out to document the ability of the DP vessel to keep position after single failures associated with the assigned equipment class and validate the FMEA and operations manual. The type of tests carried out and results should be recorded and kept on board.*

As most classification societies use the IMO MSC/Circ. 645 or IMO MSC/Circ. 1580 principles as the basis for their own DP rules it will be a condition of class that the vessel has conducted DP annual trials.

MTS DP Operations Guidance - Part 1 gives further guidance and details on when annual trials should be conducted and what they should test:

> *4.8.4 Annual DP Trials:- A series of tests of fault and failure conditions relevant to the DP System. The tests should be designed to prove system redundancy, as defined in the DP FMEA, system and equipment functionality, to validate repairs and preventive maintenance, and test the operation of protection and detection devices and responses so as to demonstrate that the vessel's DP system remains fit for purpose. Annual DP Trials should be performed at a specific once a year within 3 months of the anniversary of the previous year's trials. Annual DP Trials also provide the opportunities for training of the vessel's crew and enhancement of their knowledge of failure modes and their effects.*

However it is IMCA's document Guidance for Developing and Conducting DP Annual Trials Programmes IMCA M 190 Rev. 2.1 January 2020 (paywall protected) that offers the most comprehensive description of the development, conduct and management of DP annual trial programmes for all types of vessels equipped with DP systems meeting the requirements of IMO equipment classes 1, 2 or 3. IMCA M190 states that the aims of annual DP trails should be to:

- *Demonstrate that the DP system is fully functional, performing as intended with full power and thrust availability;*
- *Verify the level of critical redundancy established by the FMEA;*
- *Verify the effectiveness of essential protective functions and alarms;*
- *Verify that the failure modes and effects of any modifications or upgrades are fully understood and incorporated into the FMEA and operational procedures;*
- *Meet the testing and survey requirements of IMO Guidelines for vessels with DP systems*
- *Meet the requirements of the classification society for annual and periodical renewal survey (as appropriate);*
- *Be an effective tool for verifying, updating and generally managing the FMEA, thereby avoiding the need to redo the FMEA.*

IMCA M190 further explains the methodology of an annual trials programme carried out on redundant systems as an attempt to prove that the three elements of

> *Performance;*
> *Protection; and*
> *Detection.*

are present where required.

It should be noted that the guidelines in IMCA M190 allow for annual trials testing to be undertaken on an incremental basis throughout the year, providing the tests are completed within a twelve- month period. IMCA have recently released an Information Note (IMCA Information Note 1496) to clarify this position. IMCA notes that:

> *IMCA has become aware that some vessel owner/operators are undertaking a fixed percentage of an overall trials programme per year on the basis that over 5 years the full programme has been completed. This is not in compliance with IMO and IMCA guidelines Guidance for developing and conducting DP annual trials programmes (IMCA M 190).*

And reminds us that a DP annual trials programme is the overall programme of tests to satisfy the **annual** survey requirements of IMO MSC/Circ. 1580

IMCA DP PRACTITIONER ACCREDITATION SCHEME

IMCA M190 states that

> *5.2 Independent verification of testing intended to prove the integrity of systems where the consequences of failure can be severe is desirable.*

and tells us that the independent witnesses

> *should be sufficiently removed from day-to-day operational control or responsibility for the DP system and vessel. They should also be familiar with the vessel or type of vessel and with the DP annual trials programme.*

Further, IMCA M 190 recommends that the independent witness is accredited according to the IMCA DP Practitioner Accreditation Scheme.

GUIDANCE, PURPOSE, REQUIREMENTS, WHAT SHOULD BE DEMONSTRATED

MTS DP Operations Guidance - Part 1 defines field arrival trials as,

> *A series of checks and tests that confirm satisfactory performance of the DP system and verify the set up mode of operation and DP functions.*

and IMCA M103 states that

> *These checks should be carried out on arrival at the field and conducted outside the 500 metre safety zone. The checks should be repeated when the vessel returns to the field after an absence of more than 24 hours.*
>
> *The purpose of these checks is to ensure satisfactory operation of the DP system. The checks should include full functional checks of the operation of the thrusters, power generation, auto DP and independent joystick (IJS) and manual controls. The checks also ensure that the DP system is set up correctly and that the manning is adequate.*

IMCA issued a freely available *Information Note* in December 2022 offering guidance on what should be tested or checked during field arrival trials. This includes:

- ***Configuration/Location Checklist*** *– It is critical that the vessel configuration is verified as configurations can change during periods of transit. Many station keeping events reported to IMCA can be traced back to errors in power & DP systems configuration set-up, where if they had been checked prior to entering the field could have been avoided. The configuration should match the analysis of the vessels FMEA and the ASOG.*
- ***Generator and Thruster Testing*** *– Sufficient tests to ensure that equipment is operating as intended and be able to reach their rated capability.*
- ***UPS Load Function Test*** *– UPS is operating as intended and set up correctly. UPS function testing (i.e., taking load for 30 minutes) will have been completed at annual trials and/or as part of planned maintenance system.*
- ***DP Controller Change****-over – To verify that transfer of control does not affect the position and heading keeping ability of the vessel. This should preferably be carried out whilst the vessel is making a position change.*
- ***Operator Station Change****-over – To verify that transfer of control does not affect the position and heading keeping ability of the vessel.*
- ***Independent Joystick*** *– To ensure the control station is set up correctly and in the optimum location. All operators can competently take control of the IJS and manoeuvre the vessel. A practise regime for the IJS should already exist to ensure that all operators are capable of switching to and configuring the IJS for immediate use.*
- ***Thruster Manual Lever Check*** *– Function test the changeover to manual and levers. All operators are able to competently take control of the manual lever control and manoeuvre the vessel.*
- ***Backup DP Control*** *– If one or more remote operator terminals exist, they should remain connected, ready for use and frequently tested. Switching between main and back-up DP control station should be part of the field arrival check list.*
- ***E-Stops from Bridge*** *– Function test the (thruster) e-stops from the bridge, the stops should be located close to the operator.*

- ***Testing of PRS'S Selected*** *(where possible) – The vessel can conduct a rotation check to observe any unacceptable divergence of the available position reference systems and that they are not rejected. Blind spots in communications satellite links (providing differential corrections) are also confirmed and recorded.*

- ***DP Model Test*** *– When the vessel has been stable on DP under the control of the main DP system for thirty minutes (or reduced where considered not to have detrimental effect on the DP model), all position references are deselected from the main DP system and the mathematical model test is conducted. Position deviation over a period of 5 minutes to be logged, by observing the DGNSS systems. Critical alarms noted. This can be carried out on a similar heading that the vessel will be working in the upcoming DP Operations.*

- ***Communications*** *– All communications methods should be tested between all control and mission control stations, including back up communications. Test of DP Alert status where applicable.*

- ***Mode Changes*** *– Testing the various functionality of the DP system, in particular that which is relevant to the industrial mission.*

- ***Reset of Controllers and Operator Stations*** *– It's natural for a computer to start running more slowly if it has been left on for a long time and restarting it will usually speed things up and help fix potential emerging issues. A reboot will reset the software and flush the computer memory.*

DP Operations Guidance - Part 1 tells us that

> *DP Field Arrival Checklists to be kept on board for the period set by the owner/ operator and, where relating to a DP incident permanently stored in retrievable archives.*

DP NETWORKS (VARIOUS YEARS ACCORDING TO SECTION)

IMO MSC/Circular 1580 states that a DP control system means all control components and systems, hardware and software necessary to dynamically position the vessel *including networks*.

IMO MSC/Circular 1580 states that for equipment class 2 and equipment class 3 vessels

> *Single failure criteria include, but are not limited to:*
>
> *.1 any active component or system (generators, thrusters, switchboards, **communication networks**, remote-controlled valves, etc.); and*

DP NETWORK SYSTEM - OVERVIEW & THE RISKS, GUIDANCE AVAILABLE

A vessel management system (VMS) is a remote control, monitoring and alarm system which includes a range of automatic functions, and which may incorporate the PMS. In a centralised VMS all field connections are brought to a single point, typically in the engine control room. A centralised VMS may be appropriate for smaller less complex DP vessels but for larger DP vessels such as MODUs and construction vessels the use of distributed VMSs is now almost universal. (Note that unless a DP system is standalone, then most DP systems utilise the redundant VMS network to communicate with the thruster field stations to effect control and feedback of the thrusters.)

IMCA states that s distributed VMS offers many advantages including:

- *reduced control cabling;*
- *reduced failure effect;*
- *diversity of control locations;*
- *ease with which system can be split to match the redundancy concept.*

In a distributed VMS the hardware and software which controls / monitors equipment is in field stations positioned close to the equipment, reducing the length of cable runs. Each field station is connected to two separate communications networks via network hubs or switches. These switches connect together to form the network 'backbone'. Operator stations provide the human–machine interface (HMI) and are connected to the network in the same way as the field stations.

IMCA M103 states that the data communications network for a VMS is generally designed to be dual redundant and that,

> *The networks should be provided with a high degree of mechanical protection, particularly in areas of higher risk. In DP equipment class 3 designs there are requirements for physical separation and appropriate fire protection, including watertight integrity being maintained between the cable routes for each network. Some classification societies require similar physical separation for DP equipment class 2 designs.*

The use of industrial ethernet as a communications protocol is almost universal, typically utilising fibre optic connections. IMCA M103states that the advantages of fibre optic connections compared to copper wire are,

- *externally coupled noise immunity;*
- *bandwidth;*
- *preventing the transfer of electrical faults including those created by the effects of fire and flooding.*

Although triple redundant systems can be used, evidence suggests that those few incidents that have defeated the redundancy of dual networks would also have defeated triple redundant systems. The emphasis should therefore be to protect dual redundant networks against internal and external common cause failures rather than adding additional communications redundancy.

Vessel downtime associated with failure of Ethernet links can be addressed by carrying critical spares such as network switches and interface cards and by including spare fibre optic cores in the backbone cables which are already terminated and ready for use.

The vast majority of faults will be network switches failing (internally or power supply). This testing is easy to accomplish by the crew and should assist with fault diagnosis if a real fault should occur during active operations.

DP NETWORK SYSTEM - OPERATIONAL & FAILURE CONSIDERATIONS

Communication network failures have been identified in high profile incidents involving DP vessels over the years. The cause of several of these network failures was specifically attributed to a **netstorm.**

MTS – TECHOP ODP 08 Annual trials GAP analysis states that

> *"Network storms are a potential common mode failure capable of causing a drift off. All modern networks are fitted with protection against this type of failure. This protection must be checked periodically to confirm it is operational and that alarms to indicate that it is operating are working."*

A netstorm is an excessive amount of traffic, or more specifically, a flood of packets on the network. In a control system network scenario, the vastly increased number of packets can cause controllers to become overloaded, unable to handle their normal tasks – such as controlling a thruster (DP), monitoring shutdown conditions (ESD), or providing switchboard protection (PMS).

Netstorm hinders valid data packets on an Ethernet network in the same way. Successful delivery cannot be guaranteed under netstorm conditions. Packets can be lost or delayed to the point they are worthless. Such delay is not acceptable in a real-time control system.

A netstorm could affect different control systems in the following ways:

- A netstorm on a DP control system has the potential to cause a loss of position, this can occur due to reference system signals not being received by the controller, or thruster/rudder command signals not being delivered.
- A netstorm on a Thruster Control System (TCS) has the potential to cause a loss of position, this could occur due to a thruster field station stopping if the controller became overloaded.
- A netstorm on a Power Management System (PMS) has the potential to cause one or more generators to shutdown unintentionally, thus causing a partial or full blackout. This could result in a loss of position while on DP.
- A netstorm on an Emergency Shutdown System (ESD) system has the potential to cause unwanted shutdowns or inhibit a genuine shutdown command. This could result in a loss of position while on DP.
- A netstorm on an Integrated Automation System (IAS) system has the potential to cause loss of position while on DP, due to the integrated nature of systems, many signals can be affected, or not correctly processed if the controller became overloaded.

MTS – TECHOP ODP 08 Annual trials GAP analysis advises that

> *Comprehensive tests for a network storm should be carried out during FAT and FMEA proving trials to ensure that such an event cannot fail both networks."*

Note that while the switches have a possibility of malfunction and causing a netstorm this would be likely to occur on one of the two networks. The clients on the networks are generally controllers, HMI PCs etc and they are transmitting and receiving data from the networks. If they malfunction, then this could affect both networks simultaneously. It is important that all active nodes are checked/tested and that if any software updates are made, that netstorm resilience is also confirmed following such a change.

Netstorm testing is normally carried out by the supplier of the DP/VMS system.

However, there are several independent companies that offer such testing but often the DP suppliers will push back against such testing.

DP NETWORK SYSTEM - LESSONS LEARNT FROM DP EVENTS DP NETWORK SYSTEM

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Bulletin 01/19 February 2019	Event 3: Planned investigation resulted in DP incident

PRACTICAL ONBOARD EXERCISE

Referring to MTS DP Techop D-12 Management of intermittent faults (TECHOP (D-12 - Rev1 - May23) MANAGEMENT OF INTERMITTENT FAULTS)

Consider the network storm examples 1 and 5 (3.5.1 and 3.5.6) and discuss if a similar event could occur on your own vessel.

Discuss what might be an appropriate course of action in the event of a total thrust loss in the event of a network storm, are there any other ways to control the vessel that are not reliant on the networks?

Find out when a Network Storm test was last done on your vessel.

ABOVE AND BEYOND

Review the document IMCA M 259 DP System Network Storm Guidance September 2022

REDUNDANCY CONCEPTS

This section contains information on the following topic areas as defined by the Nautical Institute.

Redundancy Concepts
Worse Case Failure (WCF) & Worst Case Failure Design Intent (WCFDI) - explained
DP Capability plots - Purpose, IMO / Class requirements.
Open/closed bus operations - Rules, guidance, considerations, risks,
Configuration - The importance of the FMEA, consequences of configuration errors
Cross Connections - the risks and managing those risks

WORSE CASE FAILURE (WCF) & WORST CASE FAILURE DESIGN INTENT (WCFDI) EXPLAINED

See also THE REDUNDANCY CONCEPT section.

Worst Case Failure Design Intent (WCFDI) refers to the design philosophy that considers the most extreme and adverse conditions following a single fault, that a vessel might face during its operations. It aims to ensure that the vessel and its systems are robust enough to withstand the worst-case scenarios. The WCDI ensures that the vessel's position and / or heading can be maintained even under worst-case scenarios failures within a particular operating environment.

IMO MSC/Circular 1580 defines worst case failure design intent as:

> *1.2.24 Worst-Case Failure Design Intent (WCFDI) means the specified minimum DP system capabilities to be maintained following the worst-case failure. The worst-case failure design intent is used as the basis of the design. This usually relates to the number of thrusters and generators that can simultaneously fail.*

And worst case failure as:

> *1.2.25 Worst-Case Failure (WCF) means the identified single fault in the DP system resulting in maximum detrimental effect on DP capability as determined through the FMEA.*

MTS DP Vessel Design Philosophy Guidelines (Rev2 – Apr21) further explain WCF and WCFDI as:

> *The worst-case failure design intent (WCFDI) describes the minimum amount of propulsion and control equipment remaining operational following the worst-case failure. The worst-case failure design intent is used as the basis of design. Single fault tolerance is to be achieved by the provision of redundant systems. In a successful design WCF = WCFDI.*

Along with the vessel's basic redundancy concept the WCFDI should be developed as a critical part of the vessel's design process and before orders are placed for long lead items such as engines and thrusters are ordered.

Designers and naval architects will have established the amount of thrust required based on the worst anticipated environment. The equipment required to provide the stipulated uptime in the expected range of operating conditions will determine the required post worst case failure DP capability.

The redundancy concept will determine how that post failure DP capability is provided by establishing the number of generators and thrusters available after worst case failure.

When the redundancy concept is developed there may be several failures that have a severity equal to the worst-case failure design intent (WCFDI). When designing the vessel focus should be on minimizing the number of failures equal to the WCFDI.

These failures should be reviewed to determine whether a cost-effective improvement can be made. When considering cost benefit analysis, it is the lifecycle cost that should be considered including the penalties for non-availability.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) offers us an example

> *For example, the worst case failure design intent for a particular vessel accepts that three out of six generators may be lost as the result of a single failure. The design is such that this failure effect may occur because of a main switchboard bus bar failure or because a 24Vdc power supply fails. Given the relative probabilities of failure, it may be cost effective to provide a second 24Vdc power supply or possibly one for each generator. This would reduce the severity of the failure effect associated with the 24Vdc supply system.*

Section 10 of MTS DP Vessel Design Philosophy Guidelines suggests that the benefits of incorporating the design features of independence, segregation, critical redundancy, non-critical redundancy and monitoring **beyond** Class

Requirements should be considered to facilitate the vessel meeting the objectives of its industrial mission as well as a certificate of class.

It addresses the following DP marine systems

1. *Fuel oil system.*
2. *Seawater cooling systems.*
3. *Fresh water-cooling systems.*
4. *Compressed air.*
5. *Lubricating oil systems.*
6. *HVAC and ventilation.*
7. *Remote controlled valves.*
8. *Watertight integrity /Subdivision Integrity.*
9. *Pipe work.*

and offers considerations in addition to classification stipulations. It is impossible to discuss every system assessed in section 10 but we highlight here section 10.2 Fuel Oil as an example:

10.2 FUEL OIL

10.2.1 Fuel Oil systems should be designed to provide one per engine room or minimum of two for DP Class 2 and 3.

10.2.2 There should be sufficient redundancy in the fuel transfer system to allow each engine room access to the vessel's entire fuel capacity following any single failure.

10.2.3 Actuators for Quick Close Valves should be installed on a per engine basis - any remote- control system should fail safe in respect of position keeping.

10.2.4 Water content monitoring with remote alarms should be installed.

10.2.5 In addition to Class rule stipulated level monitoring, fuel level monitoring appropriate to the Industrial mission should be considered.

10.2.6 Fuel filter arrangements should be designed to facilitate changes without taking equipment out of service.

10.2.7 The design of the fuel system should facilitate isolation of services between station keeping and industrial functions if applicable.

10.2.8 Height of the day tanks for fuel should be designed to avoid dependence on emergency generator for black out/black start.

10.2.9 Co-location of auxiliary systems supporting fuel systems should be avoided. Where segregation is chosen as a design principle, it should follow the redundancy concept.

EXERCISE SCENARIO	LOSS OF REDUNDANT GROUP (E.G. PORT SW/BD)

Objective:

To observe the reaction of the crew and verify vessel's remaining capability following loss of any one redundant group.

Method:

With the vessel in full auto DP control; power plant configured according to the vessel's DP FMEA and DP operations Manual (and respective decision support tool); all other vessel equipment and systems set up in accordance with applicable DP checklists:

1. Vessel in a safe location. Simulated location and activities agreed and communicated to all participants.
2. Simulate the failure by tripping online generators on the applicable redundant group.
3. Observe reaction of DPO crew, DP technical personnel, the equipment, DP system behaviour and potential vessel position/heading excursions

Prior to executing, discuss the expected results:

- Is the methodology appropriate to gain the best outcome of the exercise?
- Who will be involved with the exercise and what roles will individuals have?
- What equipment will be impacted?
- What are the risks of the exercise?
- Is the exercise scenario appropriately documented?
- Who will observe and accurately record exercise data including the DP system configuration pre exercise?

Observations During Exercise:

- Is the drill procedure being followed?
- Is the equipment reacting as expected?
- Are those individuals directly involved in the exercise reacting appropriately given their assigned duties?
- Are those individuals indirectly involved reacting in an appropriate manner?
- Is the degree of participation and diligence as expected?
- What is the duration from commencement to concluding a safe outcome for the vessel?
- Bridge team should take the opportunity to take 'Footprint' plots

Actual results witnessed:

1. EXAMPLE: DP system loses redundant group thrusters. System allocates thrust so there is no loss of heading or surge control, the vessel maintains position with remaining thrusters. If vessel is set up with due regard to applicable ASOG parameters thruster and generator loads are within acceptable limits.

EXERCISE SCENARIO	LOSS OF REDUNDANT GROUP (E.G. PORT SW/BD)

Discussion Points (Post exercise):

Human Factors

- What are the potential risks due to "multi-tasking" during DP operations that may directly lead to the scenario outlined during this drill? (Examples include managing / monitoring deck operations, radio traffic, etc.)
- What are the potential risks due to distractions in the workspace (i.e., Bridge, Engine Room) that may directly lead to the scenario outlined during this drill? (Examples include routine maintenance procedures, social media, personnel interactions, etc.)
- Discuss the alternative actions / reactions that may occur in response to a similar scenario. Are there multiple paths to a successful resolution or is there a preferred solution? Why?
- Following a review of the simulated exercise and the vessel and crew's reaction, what different operator (Bridge and/or ECR) reaction(s) might be warranted if faced with a similar situation during operation?

Review of DPO and other key DP personnel reaction

- What potential gaps in the existing DP Familiarisation program have been highlighted as a result of the exercise?
- What changes / revisions should be considered for the training and familiarisation procedures?

Review the applicable checklists (ASOG CAM / TAM / DP operations Manual / bridge & engine room checklists / FMEA / DP Annual Trials programmes / etc.)

- What additional necessary actions and considerations should be addressed?
- What potential changes should be made to make the checklists more appropriate?
- What additional necessary operating conditions and parameters should be considered?
- What potential changes should be considered to make Decision Support Tools more applicable to the vessel and her equipment?
- How would these changes improve / affect the vessel's capabilities and limitations?

Conclusion:

Based on the results of the exercise and related discussions before and after, any suggestions for follow up including any corrective actions deemed appropriate should be accurately detailed and managed to close out.

IMO MSC 1580, chapter 4 Operational Requirements, states that:

> *4.5 DP capability polar plots should be produced to demonstrate position keeping capacity for fully operational and post worst-case single failure conditions. The capability plots should represent the environmental conditions in the area of operation and the mission-specific operational condition of the vessel.*

As we know from earlier sections it is the role of flag State to make all members aware of this. In reality many flag State's outsource this to classification societies. (see section DP Regulations and Guidance). One classification society, DNV GL, has produced a standard for calculating capability plots, DNVGL-ST-0111. The following diagram is an example of a DP Capability plot representing intact as well as WCF condition

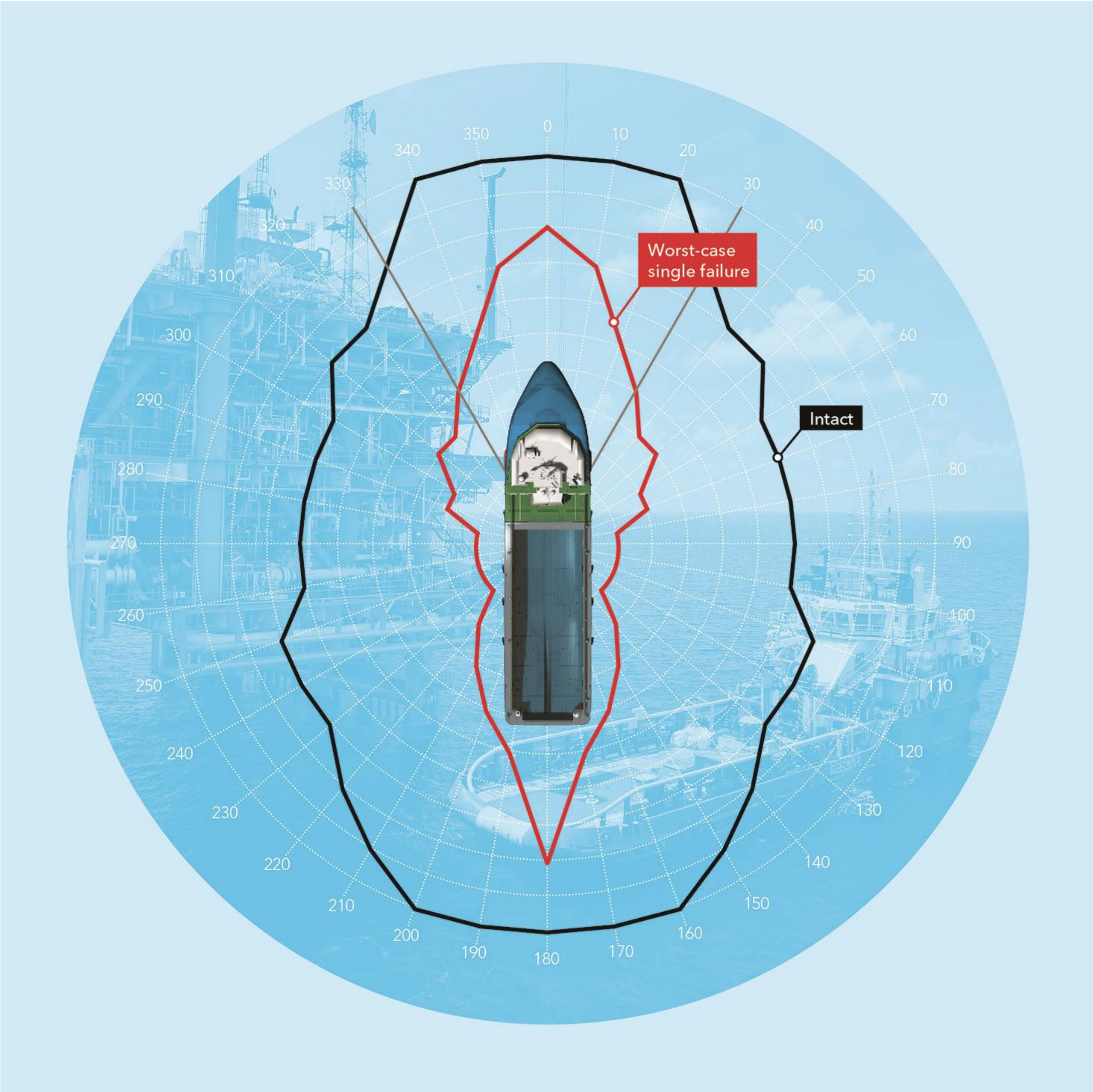


FIGURE 13 - DNV GL Example of a Level 1 DP Capability Plot Representing Intact as well as WCF Condition.

Vessel Owners or builders may employ an expert DP practitioner to write and validate the vessel's FMEA, which may include or refer to the DP capability plots.

IMCA M103 refer to capability plots as *capability analysis* and states that

> *DP capability analyses should be prepared for all DP vessels, regardless of DP equipment class*

MTS DP Operations Guidance - Part 1 explains what capability plots are in section 1 Definitions:

1.2.11 DP Capability Plots

DP Capability Plots define by theoretical calculation the vessel's capability to maintain position in various environmental conditions, (i.e. wind, sea state and current) and, where appropriate, taking account of certain external forces, such as pipe tension and, in various thruster/ power configurations, including all thrusters running, loss of most effective thruster and following worst case failure.

It expands on this in section 4.4 capability plots

4.4.1 DP Capability Plots should be calculated for the vessel. Guidance is provided on DP Capability Plots in IMCA M140 Rev 1, "Specification for DP Capability Plots".

4.4.2 These theoretical plots are calculated from detailed information of the vessel's hull and superstructure form and available thruster power. The calculations should use environmental data (sea state, wind and current) appropriate to the area in which the DP vessel is to operate.

4.4.3 These plots should show the limiting wind speed 360 degree envelopes for the scenarios below, where each point on the envelope represents the wind speed at which it is calculated that the vessel will be unable to maintain position in DP.

4.4.4 DP Capability Plots should include the following scenarios at current speeds of 0kts, 1kt and 2kts, or at other current speeds that are representative of the location in which the DP vessel is to operate:

- *Fully intact power generation and thrusters.*
- *Loss of most effective thruster(s).*
- *Following the worst case failure.*

IMCA M103requires the same categories of plots/analysis

DP capability analysis should include the following;

- *fully intact in power generation and thrusters;*
- *loss of most effective thruster(s), after worst case failure;*

They should be calculated for the intended area of operations and at current speeds of 0kts, 1kt and 2kts and any other expected current speed.

Both IMCA M103and MTS DP Operations Guidance - Part 1 refer to IMCA 140 for a detailed explanation and description of DP capability analysis/plots. IMCA M 140 is a detailed document detailing the mathematical module used to calculate the environmental forces of wind, waves and current and is above and beyond for this Learning Manual. However section 5 may be of interest:

a) Plots should be produced in polar form, with a wind speed scale between 0 and 50 m/s (15 mm = 10 m/s);

b) Wind, waves and currents should be assumed coincident in direction

c) The limiting wind speed should be plotted at least once every 15° around the vessel.

d) A minimum of two plots is required, under the same weather conditions. Plot 1 should be with all systems fully functional, that is all thrusters able to develop the maximum thrust as required. Plot 2 should be produced on the same scale as Plot 1 and represent the worst case failure mode, or an amalgamation of the worst cases.

LOCATION AND FORMAT OF DP CAPABILITY PLOTS

MTS DP Operations Guidance - Part 1 tells us in section 3.3 Recommended Documentation that

> *Hard copy DP Capability Plots relevant to the vessel's areas of operations to be readily accessible to DPOs at the DP control location.*

And in section 4.4 DP Capability Plots that

> *The DP Capability Plots should be provided in a format that is intuitive to the user on board (e.g. Polar Plot).*

PRACTICAL ONBOARD EXERCISE

Find your vessel's capability plots.

What are the limiting wind speeds at which it is calculated that the vessel will be unable to maintain position in DP for 0kts, 1kt and 2kts for each of the following scenarios

- Fully intact power generation and thrusters.
- Worst Case Failure condition and loss of the most effective thruster(s).
- Following the worst case failure.

Does the specific operating location of your DP vessel have unusual current for which a capability plot has been considered? What is the limiting wind speed envelope for each of the three scenarios listed above?

Do you understand the relationship between the wind speed and the wave height?

What are your vessels operational limits for the environment (diving may cease at a particular sea current, PSV deck operations may be limited by deck movement induced by waves, lifting operations may be limited by wind speed etc)

Does your DP operations manual / ASOG require 'on-line' capability assessment of the current environment and expected environment (due to changes, tidal, squall etc) Are you familiar with the on-line system?

ABOVE AND BEYOND

Access IMCA M 140. How does thruster efficiency and any potential discrepancies in the thruster module effect the accuracy of capability analysis/plots? How should these discrepancies be minimised?

IMO MSC/Circular 1580 defines a bus-tie as:

> *1.2.2 Bus-tie breaker means a device connecting/disconnecting switchboard sections ("closed bus-tie(s)" means connected).*

And states that

> ***For equipment class 2,*** *the power system should be divisible into two or more systems so that, in the event of failure of one sub-system, at least one other system will remain in operation and provide sufficient power for station keeping.* ***The power system(s) may be run as one system during operation, but should be arranged by bus-tie breaker(s) to separate the systems automatically upon failures*** *which could be transferred from one system to another, including, but not limited to, overloading and short circuits.*
>
> ***For equipment class 3****, the power system should be divisible into two or more systems so that, in the event of failure of one system, at least one other system will remain in operation and provide sufficient power for station keeping. The divided power system should be located in different spaces separated by A-60 class divisions. Where the power systems are located below the operational waterline, the separation should also be watertight.* ***Bus-tie breakers should be open during equipment class 3 operations*** *unless equivalent integrity of power operation can be accepted according to paragraph 3.1.4.*
>
> > *3.1.4 For equipment class 3, full redundancy of the control systems may not be possible. (i.e. there may be a need for a single changeover system from the main computer system to the backup computer system). Such connections between otherwise redundant and separated systems may be accepted when these are operated so that they do not represent a possible failure propagation path during DP operations. Failure in one system should in no case be transferred to the other redundant system.*

IMCA M103 states that:

> *The most robust fault-tolerant switchboard configuration is most likely to be achieved by operating in open bus tie mode. The switchboard may be configured with closed bus ties provided that the FMEA and a thorough analysis have demonstrated that this provides an equivalent degree of fault tolerance to open bus tie mode;*

The critical point is that the personnel onboard the DP vessel know and understand the implications of their vessel's bus tie configuration and that the vessel is set up and tested accordingly. See also the later section DP Operations where we explore ASOG, CAM, and TAM. Note that IMCA M103states that

> *CAM and TAM refer to the system and equipment configurations of DP vessels. For example, CAM may require the DP vessel to operate with open bus ties whereas TAM may permit the vessel to operate with closed bus ties.*

CAM = Critical Activity Mode

TAM = Task Appropriate Mode

CONFIGURATION – THE IMPORTANCE OF THE FMEA

MTS have produced a TechOp that addresses the need for DP FMEA proving trials to include tests to prove the fault tolerance of diesel electrical power plants and their control systems. This acknowledge DP incidents associated with a small group of failure modes which are capable of defeating the redundancy concept of a diesel electric power plant operated with closed bus ties. Are now widely available and should be incorporated in the power plant design.

This TechOp offers tests that should form **PART** of the DP FMEA proving trials where they are considered necessary to prove the redundancy of the DP system. They may differ for equipment class 2 and equipment class 3 vessels and for different operational configuration of the power plant i.e. open bus or closed bus.

The tests should be carried on full auto DP with all DP related systems in their normal configuration for carrying out DP operations in the intended equipment class.

The test outcome will be regarded as unacceptable if the severity of the failure effect exceeds the WCFDI even if the vessel maintains position in the environmental conditions prevailing during the test.

NOTE: the following MUST be read in conjunction with and TECHOP (D-02 - Rev1 - Jan21) FMEA TESTING JANUARY 2021

4.10 CLOSED BUS DP CLASS 2 & DP CLASS 3

4.10.1 Voltage dip ride through capability: It will be necessary to demonstrate by testing that the severity of the failure effect does not exceed the Worst Case Failure Design Intent (WCFDI) following a short circuit and earth fault anywhere on the power distribution system (worst case to be demonstrated). This test is also required on DP Class 3 vessels operating with independent power systems (open busties) where colocation of consumers (DP or Non DP) introduces the potential for voltage transients to occur on power supplies intended to be separate and redundant.

4.10.2 Critical active power imbalance: It will be necessary to demonstrate by testing that the severity of the failure effect does not exceed the WCFDI following a critical active power sharing imbalance as may be caused by a fuel control system fault causing one generator to fail to full power. Failure to zero fuel should also be tested.

4.10.3 Critical reactive power imbalance: It will be necessary to demonstrate by testing that the severity of the failure effect does not exceed the WCFDI following a critical reactive power sharing imbalance as may be caused by an excitation control system fault causing one generator to fail to full excitation. Failure to zero excitation should also be tested.

4.10.4 Critical line current imbalance: It will be necessary to demonstrate by testing that the severity of the failure effect does not exceed the WCFDI following a critical line current imbalance as may be caused by a broken conductor or the single phasing of a large load.

4.10.5 Overload - load acceptance and rejection: It will be necessary to demonstrate by testing that the power plant is capable of accepting (without malfunction) the largest step load that may occur as the result of a single failure. It is accepted that load shedding systems may be used to augment the load acceptance of the engines providing tests demonstrate the load shedding system is effective and robust. Acceptable load rejection must also be demonstrated in response to the worst case loss of load.

4.11 ALL DP CLASS 2 AND DP CLASS 3 DESIGNS

4.11.1 Control network redundancy and performance: It will be necessary to demonstrate by testing that redundant control system networks for thruster and power system control are single fault tolerant and that each redundant element is capable of the necessary performance. To this end, it will be necessary to carry out data throughput tests and network storm tests on each channel (Net A & B). The trials program should include tests to confirm the independent joystick remains operational with both networks in a failed state.

4.11.2 Automatic blackout recovery: Where automatic blackout recovery is required by the DP notation or by the owner's FMEA specification it will be necessary to carry out tests to demonstrate fully automatic blackout recovery. The blackout will be initiated by simulating suitable power system failure conditions and not only by stopping engines (generator 'protection trip' and 'engine stop' should both be used as means of initiating blackout).

CONFIGURATION - CONSEQUENCES OF CONFIGURATION ERRORS

Most vessel power systems are conceived with some cross connections in a bid to provide availability. These tend to present problems to the redundancy concept (in terms of independence of Redundant groups), so it is important that the vessel is set up or configured correctly to support the DP redundancy concept. This is defined by the CAM (Critical Activity Mode) configuration and will be reflected by the DP checklists (engine room and DP).

IMCA have released the following case studies on power plant configuration and its consequences.

DP Event Bulletin	ITEMS
01/23 – January 2023	Case Study – Closed Bus – Knowing the Risks Case Study – Open Bus Saved the Day Case Study – Closed Bus Ruined the Day
01/22 – April 2022	Case Study – Closed Bus Common Cause

CROSS CONNECTIONS - THE RISKS AND MANAGING THOSE RISKS

A cross connection is a connection in a DP system that can negatively influence more than one redundancy group. They have the potential to transfer a fault from an unhealthy redundancy group to a healthy one which may result in a failure in excess of the worst case failure stated in the FMEA, and consequent position and/or heading loss.

They are generally included in the design to meet availability goals or dead ship recovery etc. Often the designer considers the 'failure' of that cross connection as wire break/fail dead, but not failing to a high voltage or some other dangerous condition that then may have a detrimental effect greater than the WCF. Examples can be battery systems, control supplies for critical equipment, power supplies from the emergency switchboards etc.

Of particular concern would be power supplies from different redundancy groups on a DP3 vessel where a fire or flood of a compartment can result in both supplies being short circuited. Normally the protection will isolate, and if coordination is correctly done there are no further consequences, but if there is a hidden fault on the upstream CB and it does not trip on the fault condition, then to isolate the fault we may have to lose that entire distribution panel. Has this been considered?

Where common points exist between redundant systems, risk assessments on impacts of failure propagation should be carried out, documented in the FMEA, verified and validated through appropriate testing and adequately mitigated.

Typically, some cross connections are inevitable, such as the redundant communication networks, fire/gas safety systems, the air we used for the engines, atmosphere affecting GNSS, the DP system etc. Some we create out of choice, so typically closed bus systems, isochronous load share lines etc.

Comprehensive analysis should be carried out and identified in the FMEA where common points and / or cross connections are identified. Validation testing should be based on the engineering basis (comprehensives analysis). The burden of a such activities (including skill levels) should not be underestimated.

It is increasingly common for cross connections to be expressed in the form of a Venn diagram for subject areas within the FMEA. This allows for a very quick assessment of subject autonomy within the DP System. A series of Venn diagrams are show in Figure 3.

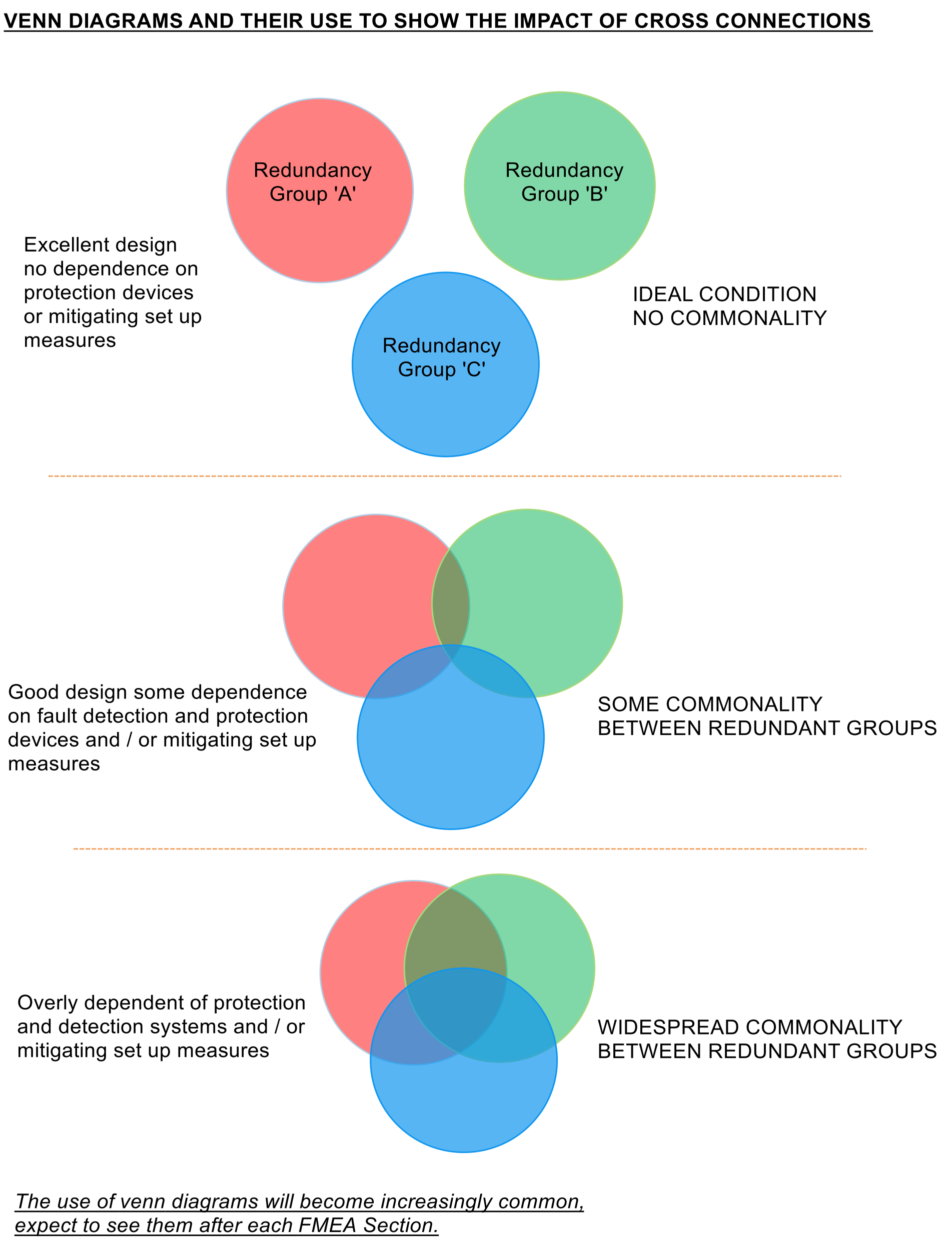


FIGURE 14 - VENN DIAGRAMS REPRESENTING CORSS CONNECTIONS

IMCA M 247 Cross Connections and Automatic Changeovers offers some guidance

4.4.5 Cross connections and automatic changeover consumers, such as thrusters, require considerable attention from a failure perspective as poor designs have led to many DP incidents in recent years. The fundamental issue being the ability to potentially defeat the redundancy concept by cross connecting power supplies for DP equipment or permitting the transfer of a fault across the redundancy split. It may not be possible to achieve absolute separation across redundant systems and cross connections may exist between the redundant groups to allow common control of generators, switchboards and thrusters. The FMEA should therefore consider the source of equipment power supplies in detail, considering the effects of the various potential failures of such supplies, and any common failures associated with non-DP equipment connected to the same source. The FMEA should also consider the mechanisms or interlocks in place to inhibit the auto transfer of a faulty consumer if it develops a fault. This is also true for generators, but less likely because of the need for generators to be synchronised before connection is permitted.

There are many potential cross connections/automatic changeover failure examples:

- *Control power supplies for main switchboards connected by a fused diode bridge – no fuse monitoring and a hidden failure;*

- *Critical feeds with primary source of power from the emergency switchboard – creating a potential common mode failure;*
- *Governors supplied with common power supply, with a number of sources – an unrelated consumer on the same distribution developed a fault leading to all governors failing;*
- *A changeover thruster developed a fault causing the changeover system to trigger thus transferring the fault to the healthy power supply;*

Backup supplies are one area where the provision of redundancy can increase the risk of a DP incident if not carefully considered. Consider an electronic governor system properly split along the lines of the redundancy concept, with governors for each half of the power plant off separate 24V DC supplies. For 'extra' safety, the two supplies were tied together so that if one failed the whole power plant would continue to operate from the other. If there are no alarms to indicate that one of the supplies has failed the vessel may be operating on DP on a single system and the operators would be completely unaware that these systems are no longer redundant, representing a serious hidden failure. When the remaining supply fails, the entire power plant is lost, and loss of position occurs. Providing comprehensive failure detection for DC supplies can be challenging. Typically, such systems offer under-voltage indication to give warning that the supply has gone over to batteries or mains failure indication but may not indicate connection to the load has been lost. Systems based on measuring the current being delivered to the load may not be effective as DC supplies do not inherently load share (unless designed that way). Even with two healthy units, only one may be providing all the power. The FMEA should highlight any such arrangements that introduce unnecessary commonality in the redundancy concept. If there is a desire to reduce the impact of a 24V DC supply failure, it is better to give each half of the system two independent supplies than to cross connect the two sides of the power plant.

Other concerns with common backup supplies include various types of common mode failures. In one example, a vessel had six electronic thruster control units each with a 220V AC supply and a backup 24V DC supply. However, the backup 24V DC charger failed and briefly put 220V AC onto the 24V DC lines. As this supply was common to all thrusters, all electronic control units were damaged, and the vessel lost position.

MTS DP Vessel Design Philosophy Guidelines – when talking about predictable outcomes in section 3 offers this:

3.2.2 The phrase 'the three Rs' have been adapted to DP to mean:

- *Redundancy*
- *Reliability*
- *Resilience*

Redundancy: The ability of a system to restore or maintain its function following a failure
Reliability: The ability of a system to remain in operation for a specified period of time without malfunction.
Resilience: The ability of a system to withstand a failure and to continue in operation following failure. It may include the ability to recover from a failure without suffering significant damage.

Cautionary note 1. An oft observed vulnerability in designs is the presence of cross connections between redundancy groups. Introductions of such cross connections are usually well-intentioned attempts to enhance fault tolerance. However, the potential for such cross connections to serve as fault propagation pathways (capable of failure effects exceeding the severity of the worst-case failure design intent) is often not recognized or understood and this is reflected in the lack of comprehensive analysis, verification and validation.

Cautionary note 2: The temptation to equate the term robustness to the three 'Rs' should be avoided. Equipment performance indicators may mask the potential for equipment to fail catastrophically beyond a point where resilience is compromised, and failure effects exceed the worst-case failure design intent with no possibly of recovery. (example, automatic blackout recovery)

And

3.4.2 It is apparent, when considering the influence of the various pillars, that they fall into two distinct groups. The three pillars on the left are dominant in designs with very few cross connections and therefore fault propagation *paths between equipment groups intended to provide redundancy. The three pillars on the right are required when there are fault propagation paths to be mitigated. Focus on the left diminishes the need for the attributes on the right. But the reverse becomes true when cross connections are introduced. The attributes on the right (fault resistance, tolerance and ride-through) also introduce an additional Lifecyle test burden to prove they are still effective.*

And

4.17 CONNECTIONS BETWEEN REDUNDANT SYSTEMS

4.17.1 Experience suggests that common connections between systems intended to provide redundancy create the paths by which a fault in one redundant system may affect another independent system. Some connection points are unavoidable such as remote-control systems and those introduced to achieve additional objectives (example – reduction of emissions, hybridization etc.) and may be beneficial to the design. Where common points exist between redundant systems, risk assessments on impacts of failure propagation should be carried out, documented in the FMEA, verified and validated through appropriate testing and adequately mitigated.

4.17.2 Comprehensive analysis should be carried out and identified in the FMEA where common points and / or cross connections are identified. Validation testing should be based on the engineering basis (comprehensives analysis). The burden of a such activities (including skill levels) should not be underestimated.

When considering Power systems in section 11

11.1.11 In good redundancy concepts, the split between the power systems is clearly defined and there are few cross connections between systems. Where cross connections are unavoidable, they should be easily identifiable. In these types of redundancy concepts, failures within each independent power system should only affect thrusters and generators in one of the power systems.

11.1.12 In poorly defined redundancy concepts, the boundaries between each power system are more difficult to identify and there may be a larger number of shared components or connections. Vessels with this type of redundancy concept are susceptible to failures that could exceed Worst Case Failure Design Intent (WCFDI). Even if WCFDI is not exceeded, failure in one power system may affect generators and/or thrusters in the other power system and different combination of thrusters may be lost. Multiple failure permutations exist in such systems.

PRACTICAL ONBOARD EXERCISE

Access your vessel's FMEA. Does your vessel have any cross connections that might propagate failure? What are they and how are they represented on you FMEA.

If you can, access the last set of vessel trials and see how these were tested and impacts mitigated.

ABOVE AND BEYOND

Access the Dynamic Positioning app and read the Expert Piece on Cross Connections

Access and read MTS Techop ODP-17(D)

DP Position Reference Systems and Sensors
Introduction to Position References & Sensors
Different Principles including relative & absolute and general challenges e.g., blocking of signals
Considerations for appropriate selection of PRS for DP operations
PRS Interaction and calibrating PRS
PRS Lessons learnt from DP events
DGNSS
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Laser
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Laser (No Reflector)
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Microwave
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Hydroacoustic
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
INS
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Taut Wire
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Gangway Sensors
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events

New developments in last 5 years
Wind Sensor
Overview, advantage, disadvantage, inc. how wind profiles can be affected by assets
Operational & Failure considerations
Lessons learnt from DP Events
New developments in last 5 years
Heading Sensor
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events INS
New developments in last 5 years
MRU / VRU
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events MRU
Current Sensor
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events DGNSS
New developments in last 5 years
Tension Sensor
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events Tension sensor
New developments in last 5 years
Draft Sensor
Overview, advantage, disadvantage
Operational & Failure considerations
Lessons learnt from DP Events Draft sensor
New developments in last 5 years

The function of a DP systems is to hold the vessel in a designated position and or on a designated heading. It does this using the vessel's power and thrust to counteract the environmental forces of wind tide and current.

For the DP systems and the DPO to know that the vessel is in the correct position, the use of the most accurate and most reliable position reference systems is critical.

IMO MSC/Circular 1580 3.4.3 Position reference systems states:

> *.5 The position reference systems should produce data with adequate accuracy and repeatability for the intended DP operation.*

The word repeatability means that the position reference system will accurately repeat the vessel's position over and over again; is the position reference system reliable?

There are many different position reference systems for the DPO to choose from when setting up on DP mode. But they are not all suitable or safe for every DP operations.

IMO MSC/Circular 15803.4.3 Position reference systems tells us that

.1 Position reference systems should be selected with due consideration to operational requirements, both with regard to restrictions caused by the manner of deployment and expected performance in working situations.

The number of position refence systems that need to be selected by the DPO is defined by the equipment class of the DP vessel in question.

<u>IMO MSC/Circular 1580</u>

3.4.3 Position reference systems

> *.1 Position reference systems should be selected with due consideration to operational requirements, both with regard to restrictions caused by the manner of deployment and expected performance in working situations.*
>
> *.2 For equipment class 1, at least two independent position reference systems should be installed and simultaneously available to the DP control system during operation.*
>
> *.3 For equipment classes 2 and 3, at least three independent position reference systems should be installed and simultaneously available to the DP control system during operation.*
>
> *.4 When two or more position reference systems are required, they should not all be of the same type, but based on different principles and suitable for the operating conditions.*
>
> *.5 The position reference systems should produce data with adequate accuracy and repeatability for the intended DP operation.*
>
> *.6 The performance of position reference systems should be monitored and warnings should be provided when the signals from the position reference systems are either incorrect or substantially degraded.*
>
> *.7 For equipment class 3, at least one of the position reference systems should be connected directly to the backup control system and separated by an A-60 class division from the other position reference systems.*

3.4.4 Vessel sensors

> *.1 Vessel sensors should at least measure vessel heading, vessel motions and wind speed and direction.*
>
> *.2 When an equipment class 2 or 3 DP control system is fully dependent on correct signals from vessel sensors, these signals should be based on three systems serving the same purpose (i.e. this will result in at least three heading reference sensors being installed).*

.3 Sensors for the same purpose which are connected to redundant systems should be arranged independently so that failure of one will not affect the others.

.4 For equipment class 3, one of each type of sensor should be connected directly to the backup DP control system, and should be separated by an A-60 class division from the other sensors. If the data from these sensors is passed to the main DP control system for their use, this system should be arranged so that a failure in the main DP control system cannot affect the integrity of the signals to the backup DP control system.

Within the guidelines given above it is important to understand the criticality of each sensor and reference to the operation.

Generally, a WSOG or ASOG will specify the critical limits for any off position or off heading. Clearly if a reference we intend to use has a standard deviation larger than this limit it is unsuitable as a primary reference, (though it still may be better than nothing if the others fail!)

PRACTICAL ONBOARD EXERCISE

Discuss why we have three Gyros, 3 MRUs and 3 wind sensors?

Discuss the criticality of each type of sensor and the effects that a failure would have on the DP system and any Reference systems.

Discuss what DP modes and references are appropriate for moving targets i.e. ROV, Pipelay (continuous/welded sections etc), FPSO, spar etc.

DIFFERENT PRINCIPLES INCLUDING RELATIVE & ABSOLUTE AND GENERAL CHALLENGES EG, BLOCKING OF SIGNALS

MTS DP Operations Guidance - Part 1 lists types of PRS under the heading of absolute and relative

> ***4.6 POSITION REFERENCE SYSTEMS AND SENSORS***
>
> *4.6.2 Position reference systems comprise absolute and relative systems. An absolute system gives vessel geographical position. A relative system gives vessel position in relation to a non-fixed reference. A relative system can be used as an absolute system if installed on a point that is a fixed geographical position and an acoustic absolute system can be used as a relative system if attached to a non-fixed asset.*

Absolute	*Relative*
DGNSS (DGPS and GLONASS)	*Laser (Fanbeam, Cyscan)*
Acoustic (USBL, SBL, LBL)	*Radar (RADius, RadaScan)*
Taut Wire	*DARPS*

Note – Acoustics may give an absolute fix IF the LBL array is in a surveyed position. Often USBL and SSBL will be a fix relative to a beacon deployed by the vessel to the seabed. The Taut wire systems tend to be relative to the point the clump weight was deployed. DARPS is generally used to measure relative position but it also has absolute capability.

Radar should also include Artemis. Laser should include SpotTrack.

A gangway can also be used to determine the distance between the vessel and either a fixed platform or a moving vessel (FPSO etc) (though it will depend on the type of gangway)

The Acoustic (SSBL and USBL) the laser, radar, DARPS can have targets fixed to a **moving object** (vessel, FPSO, ROV etc) and then they are delivering a Relative measurement to the target. In the DP they are defined as **mobile** (rather than fixed)

It is vital that the DPO is aware of how the PRS is configured (Fixed / Mobile), what mode the DP is in and can that PRS be used in that mode, and what references can be used together (are they measuring the same basis of fixed or mobile).

Some DP modes allow the use of both fixed and mobile measurements. In 'follow' modes often the DP will hold position based on a fixed / absolute measurement (often just GNSS). The 'mobile' measurements are used to estimate if the target has moved outside of a 'reaction radius'. If so, then the new fixed target position is calculated, and the vessel moves to the new position.

CONSIDERATIONS FOR APPROPRIATE SELECTION OF PRS FOR DP OPERATIONS

MTS DP Operations Guidance - Part 1 tells us that the selection of PRSs needs to be made with due regard to the vessel's specific operational activities.

> *4.6.1 The DP vessel should be equipped with suitable position reference and sensors in accordance with the vessel's DP class notation and operational requirements. Position reference systems should be selected with due consideration to operational requirements, both with regard to restrictions caused by the manner of deployment and expected performance in working situations.*

It is important to remember that

.4 When two or more position reference systems are required, they should not all be of the same type, but based on different principles and suitable for the operating conditions. (IMO MSC/Circular 1580)

This is so the vessel's DP system does not experience common mode failures.

An interesting conflict to the requirements of IMO / MTS is that there are many vessels where two DGNSS and a single relative reference are fitted and this is allowable by the Classification Society to meet a DP 2 notation. This is despite DGNSS having common mode failures that could effect both systems at the same time. In this scenario it is incumbent on the DPO to understand the limitations of this arrangement and particularly close attention should be paid to satellite health.

MTS DP Operations Guidance - Part 1 also offers a cautionary note on balance of position references:

> *Caution Additional position reference systems should be based on different principles. It is generally not recommended to use multiple (>2) satellite based systems in conjunction with other positions reference systems as this may result in skewed weighting in favour of multiple satellite systems.*

If you are on an equipment class 3 vessel you should check your DP operations manual or FMEA to make sure that at least one of the position reference systems is connected directly to the backup control system and separated by an A-60 class division from the other position reference systems.

IMCA 103 offers some guidance on checking the vessel has the correct position reference systems selected before DP operation commence.

> *DP Location Set-up Checklist*
>
> *The purpose of these checks is to ensure that the vessel's station keeping performance at the working location is satisfactory and, in particular, to ensure that the position reference systems are properly set up.*

Critically no PRS is completely accurate all of the time so constant vigilance is needed when operating in DP. IMO 1580 3.4.3 Position reference systems states

> *.6 The performance of position reference systems should be monitored warnings should be provided when the signals from the position reference systems are either incorrect or substantially degraded.*

PRS INTERACTION

In dynamic positioning systems, integrating of data from position reference systems is a process that combines the data from multiple sources to produce an accurate and reliable estimate of the vessel's position from independent sources. This process minimizes the effects of errors from individual PRS and provides a more robust solution by combining the strengths of multiple reference systems and reducing the impact of any single system's limitations or failures. The final position estimate is usually calculated as a weighted average or a statistical combination of the data from the individual reference systems. Often this is also weighted by the vessel model estimate of position.

There are several potential issues that could arise from integration of position reference systems data:

Incompatibility: The reference systems may use different technologies, units of measurement, or data formats, making it difficult to combine their data effectively. Though, if a PRS is available at the DP desk it would be fair to assume it is operable and has been tested through Proving and Annual Trials for robust performance.

Here's a few definitions related to PRS integrity you may come across.

Data quality: The accuracy and reliability of the data from each reference system can vary, and integration may amplify errors or bias in the final estimate if not handled properly (the DP deals with 'quality' by looking at scatter and weighting data with larger variance)

Outliers: One or more reference systems may produce erroneous data that could significantly impact the final estimate if not detected and removed, again the DP will reject outliers, it is part of the 'fix' process.

Weighting: Determining the appropriate weighting for each reference system is important for achieving an optimal balance between accuracy and reliability. If not set correctly in the DP System, the final estimate could be dominated by a single system, leading to poor performance.

Latency: If the data from the reference systems is not synchronized or has significant latency, the final estimate could be based on outdated information.

In the DP System there are a number of tests that are performed, these normally occur as part of the DP Controller algorithms, but take time to understand how your DP Controller handles PRS and what integrity testing it applies. Below are the common ones:-

Freeze test – looks for a data stream that is frozen i.e. not changing.

Variance test – tests position variance from the calculated limit.

Prediction test – detects large rapid changes in a PRS position.

Divergence test – test to detect slow position movement or a integral inconsistency.

Median test – is a test performed against three (3) or more PRS and is designed to detect a slowly drifting PRS.

CALIBRATING PRS

There are two aspects to calibration. The first is the individual PRS so for an acoustic system it is necessary to perform a calibration that uses many fixes taken over a period of time and various headings etc and this is estimating errors in the deployment machine 'verticality' etc. Other references like Laser and Radar are delivering a bearing from the device to a target. If the device is not aligned with the vessel fore/aft axis the fix will not be accurate (but would be consistently wrong) The offset of each device from the centre of the vessel will also contribute to an error in the fix. The offset uses the vessel heading to translate the device fix to a position of the centre of the vessel so if the heading is not correct this can also contribute to the vessel centre calculated position. Any pitch and roll compensation will be affected by the alignment and accuracy of the Vertical reference Units. Generally, any compensation applied for pitch, roll or heading will be amplified by the length of the range. In the case of a GNSS antenna it is the height above the centre for pitch and roll and heading if the horizontal offset is large, for acoustics it can be the slant range of the signal from the transponder (more applicable to SSBL / USBL).

The other aspect to calibration is when various references are selected due to the above-mentioned errors they will not align, and as they are selected, they will compare to the first reference (or origin) and the DP may add an offset (sometimes called bias) to each subsequent fixes.

If the operation requires a point on the vessel to be at a certain Lat/long (like drilling) then any GNSS close to that point on the vessel should be selected as the origin, as that will have the smallest absolute error due to heading error. The other references will all then 'align' to that one.

If the operation is alongside a fixed asset, we are more interested in where we are relative to the asset rather than our absolute position. For vessels like PSVs the Reference sensors are grouped fairly close together on the forecastle/mast/monkey island so errors due heading measurement will all be about the same!

Most references are self-calibrating, like GNSS, later, radar etc. but for a taut wire one critical piece of data is the water depth. Often this is a manual input value and if this is incorrect then the calculation of horizontal movement will be wrong so if we were in 200m of water, but the Taut wire was told it was 100m then if the vessel moves 10m the taut wire would calculate 5m.

Correct calibration of a position reference system in a dynamic positioning system is essential for ensuring the accuracy and reliability of the vessel's position. The following are some of the key reasons why correct calibration is important:

Accuracy: Calibration ensures that the reference system is measuring the vessel's position correctly, so that any errors or biases in the measurement can be corrected.

Reliability: Proper calibration can help to ensure that the reference system is functioning correctly and that its performance is consistent over time, reducing the risk of failure or degradation of accuracy.

Consistency: Calibration helps to ensure that the reference system is providing consistent and accurate data, even in challenging operating conditions such as rough seas, electromagnetic interference, or other environmental factors.

Integration: Calibration is important for ensuring that the reference system is integrated correctly into the overall dynamic positioning system, and that its data can be effectively combined with data from other reference systems.

Safety: Accurate and reliable positioning information is critical for the safe operation of the vessel, and proper calibration helps to ensure that the dynamic positioning system is providing the necessary information to the crew.

Calibration of sensors will impact overall DP performance. Some position references are sensitive to errors in heading, pitch, roll and heave. For example, an acoustic system in USBL/SSBL mode relies on accurate pitch and roll data. As part of the calibration process any offsets from actual vertical will have been included. So, if that MRU is moved it is unlikely to go back in exactly the same place and hence the previous offsets (pitch, roll) might not be appropriate as a consequence. Obviously if the unit itself were to fail in a way that it drifted out of calibration then the acoustic system may not recognise this error, but the DP would generally be comparing it to the other two MRUs.

PRS LESSONS LEARNT FROM DP EVENTS

MTS TECHOP (D-09 – Rev1 – Jan21) PRS AND DPCS HANDLING OF PRS lists some examples of potential failure effects associated with the incorrect handling position refence system complied form IMCAs reporting scheme.

- *Signal degradation caused by Ionospheric phenomena.*
- *Clock errors: (Example – Leap second event).*
- *GNSS drift: The fault symptom is an apparent slow drift of the GNSS measured position and is interpreted as actual vessel motion by the DP control system. There is a long history of GNSS drift problems, and in the early days of GPS it has been observed where both installed GNSS references appear to slowly drift in unison. GNSS signal drift is frequently in the same direction and at a rate slow enough to pass DP system "signal rejection" checks. In addition to reference signal standard deviation, additional parameters need to be checked. The SD of observed, slowly-drifting GNSS signals is good due to the GNSS' relatively noise-free signal characteristics as compared to acoustic.*
- *DP events have occurred in which the loss of two GNSSs was caused by the failure of a single UPS. The two units were powered by the same UPS.*
- *DPCS ability to identify a faulty position reference sensor was defeated by false indication of high GNSS quality and Integrity.*
- *Degraded signals due to shadowing: There have been reports of vessels experiencing degraded differential correction signals caused by shadowing. The shadowing can be attributed to derricks, cranes, radar masts, etc. This is an issue for OSVs coming along side drilling vessels or platforms where both corrections satellites and positioning satellites can be shadowed at the same time.*
- *Corrupt GPS or GLONASS data: Historically there have been instances when GPS or GLONASS satellites transmit corrupt data that cause position jumps or even lock-up the GNSS unit. These anomalies are rare but still a possibility. Systems that were not able to discriminate and reject satellites transmitting corrupt data were susceptible to errors leading to loss of position.*

- *Corrupt Differential Data: There have been instances when corrupt differential data cause position jumps or other issues. Most service providers have addressed this issue by improving quality control.*
- *DOP holes: There have been instances where DOP holes have resulted in poor geometry and position degradation. This can be mitigated with the choice of equipment that is capable of using multiple satellite constellations. Degraded signals due to local interference: There have been instances of vessel equipment causing interference with GNSS equipment. Examples of vessel equipment responsible for interference include:*
- *Inmarsat communications satellite systems.*
- *Satellite phones.*
- *Third party satellite communication systems (logging, etc.).*
- *Harmonic frequencies generated by faulty equipment e.g. floodlight and fluorescent light ballasts, Helicopter Emergency Beacons, etc.*
- *Re-radiating (faulty) antennas.*
- *Re-radiating (faulty) Radio Frequency (RF) cables.*
- *Degradation of Acoustic PRSs due to acoustic noise:*
- *Internal / operations generated (Example – drilling operations, thruster cavitation, ROV operations).*
- *External sources of acoustic noise: Any source not caused by the vessel or its operations. (Examples – cavitation from supply boats alongside, seismic surveys in the vicinity, acoustic signals other sources in the area, Flow in subsea pipelines, ROV operations on another vessel, autonomous underwater vehicles).*
- *Degraded performance of Acoustic PRSs dues to: (Examples – marine growth on transducer/transceiver, gate valve for transducer deployment leaking, or not operated regular basis. Loss of beacons, rigging failures, dragged off position by other vessels / activities being performed).*
- *Configuration errors – operator induced: (Erroneous settings on PRSs, DPCSs). Configuration errors – DPCS related: (Examples – DP freeze test for Acoustic PRS).*
- *Inadequate number of transponders appropriate for the industrial mission (Example – Position solution degradation from LBL to USBL being identified as a position jump)*
- *Degradation of relative positioning capability:*
- *Laser based systems (Examples – Poor reflective surfaces being used, inadequate number of targets, erroneous identification of targets, poor siting of equipment, inadequate spatial separation of targets).*
- *Microwave based systems (Examples – Inadequate number of targets, poor siting of equipment, inadequate spatial separation of targets and maintenance of transponders).*
- *Obsolescence (Hardware and Software).*
- *Lack of 'systems thinking' (Failure to consider PRS, sensors and DPCS in a holistic manner).*
- *Lack of transparency in the error ellipsoids, No harmonized standard or requirements, lack of alignment between PRS OEM and DPCS OEM on requirements.*
- *Choice of PRSs (Examples – inappropriate mix of absolute and relative PRSs, unsuitable for industrial mission being performed, inappropriate for water depth, inadequate number of transponders / targets).*

- *Choice of mode of DPCS control (Example – Follow Target Mode versus Auto Position).*
- *Operator cognitive burden (Example – Lack of attention to human factor's engineering, overload of information, access to settings not required for day-to-day operations, lack of automation resulting in erroneous and/or unwarranted operator actions / intervention).*

IMCA issued an Information Notice (No. 1567 – July 2021) because the IMCA marine DP committee identified a trend of DP station keeping events relating to the incorrect setup, use or selection of position reference systems and sensors.

DP Event Bulletin	ITEMS
DP Event Bulletin 04/21 – December 2021	Configuration – PRS's Hidden Common Failure
DP Event Bulletin 02/22 – August 2022	Relative PRS – A Reflection
DP Event Bulletin 04/20 – December 2020	Inadequate Position Reference Systems Caused DP Incident
IMCA DP Station Keeping Bulletin 04/19 November 2019	Unreliable position reference systems leads to DP incident
IMCA DP Station Keeping Bulletin 04/18 November 2018	Use of third-party equipment leads to DP undesired event

PRACTICAL ONBOARD EXERCISE

IMO MSC.1/Circ.1580 section 3.4.3 position reference systems states ".5 the position reference systems should produce data with adequate accuracy and repeatability for the intended DP operation." What does repeatability mean in this context?

Explain two ways in which the actions of a DPO are critical to the safety of DP operations with regards to position refence systems? Give one answer for before operations, and one during operations

Discuss the dependencies of References systems on Sensors.

ABOVE AND BEYOND

The following pages from the MTS Operations guide provide really good support to PRS understanding and selection. A working knowledge of this will support you to answer questions in the DP CPD assessments that relate to PRS.

	Recommended Absolute Position Reference Systems							Recommended Relative Position References Systems if in close proximity to an offshore structure								Sensors
Application on DP	**GPS**	**DGNSS (DGPS + GLONASS+) (Note 2)**	**SBL (Note 1)**	**USBL/SSBL (Note 1)**	**LBL (Note 1)**	**Taut Wire (Note 12)**	**Min Number (Note 3)**	**Artemis**	**Laser**	**Radar**	**Gangway**	**DARPS**	**Fixed Platform (Notes 4, 5 & 6)**	**TLP/SPAR <min movement (Notes 4, 5 & 6)**	**TLP/SPAR >min movement (Notes 4, 5 & 6)**	**Gyros, VRUs and Wind sensors (Note 7)**
Drilling	*if in Deep water*	*Redundant- one dual frequency*	*<700m*	*<700m*	*>700m*	*<350m*	*3*	*Y*	*Y*	*Y*	*N*	*N*	*3 mixed abs & rel*	*3 mixed abs & rel*	*3 relative only*	*3*
Diving	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*3*	*Y*	*Y*	*Y*	*N*	*N*	*3 mixed abs & rel*	*3 mixed abs & rel*	*3 relative only*	*3*
Pipelay	*N*	*Y*	*N*	*N*	*N*	*N*	*3*	*Y*	*Y*	*Y*	*N*	*N*	*3 mixed abs & rel*	*3 mixed abs & rel*	*3 relative only*	*3*
Umbilical Lay	*N*	*Y*	*N*	*N*	*N*	*N*	*3*	*Y*	*Y*	*Y*	*N*	*N*	*3 mixed abs & rel*	*3 mixed abs & rel*	*3 relative only*	*3*
Riser Pull in	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*3*	*Y*	*Y*	*Y*	*N*	*N*	*3 mixed abs & rel*	*3 mixed abs & rel*	*3 relative only*	*3*
Lifting	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*3*	*Y*	*Y*	*Y*	*N*	*N*	*3 mixed abs & rel*	*3 mixed abs & rel*	*3 relative only*	*3*
Accomodation	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*3*	*Y*	*Y*	*Y*	*Y*	*N*	*3 mixed abs & rel*	*3 mixed abs & rel*	*3 relative only*	*3*
Shuttle Offtake	*N*	*Y*	*N*	*N*	*N*	*N*	*3*	*Y*	*Y*	*Y*	*N*	*Y*	*3 mixed abs & rel*	*3 mixed abs & rel*	*3 relative only*	*3*
ROV Support	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*2*	*N*	*N*	*N*	*N*	*N*	*Note 8*	*Note 8*	*Note 8*	*2*
FPU	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*3*	*N*	*N*	*N*	*N*	*N*	*N/A*	*N/A*	*N/A*	*3*
Well Stim	*N unless open water*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*2*	*Y*	*Y*	*Y*	*Y*	*Y*	*2*	*Note 8*	*Note 8*	*2*
OSV Snatch lifts	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*2*	*Y*	*Y*	*Y*	*N*	*N*	*1*	*2 mixed abs & rel*	*2*	*2*
OSV HAZMAT Transfer with NO quick disconnect	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*3*	*Y*	*Y*	*Y*	*Y*	*N*	*2*	*3 mixed abs & rel*	*3 relative only*	*3*
OSV HAZMAT Transfer with quick disconnect	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*2*	*Y*	*Y*	*Y*	*Y*	*N*	*2*	*Note 8*	*Note 8*	*3*
OSV with Shaft Gens and single stern thruster	*N*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*2*	*Y*	*Y*	*Y*	*Y*	*Y*	*3*	*Note 8*	*Note 8*	*3*
Wind turbine Installation	*N*	*Y*	*N/A*	*N/A*	*N/A*	*N/A*	*2*	*N*	*N*	*N*	*N*	*N*	*N/A*	*N/A*	*N/A*	*2*
Standby Vessels	*Y*	*Y*	*<700m*	*<700m*	*>700m*	*<350m*	*1*	*N*	*N*	*N*	*N*	*N*	*N/A*	*N/A*	*N/A*	*1or<*

This document can be reviewed in full by following the link below:-

DP OPERATIONS GUIDANCE - PART 2 - APP 1 (Rev3 - Jan21) MODU

Note 1 (Acoustics) *– The acoustic LUSBL system is not included in the above table since it is a combination of USBL and LBL in one system, where the USBL is typically used to calibrate the LBL system. Although standalone USBL systems are not the norm on DP drilling MODUs it is not unknown for SBL and USBL systems to be operated as independent units in addition to LBL.*

The abbreviations, USBL and SSBL, are referred to in the above table. Although the abbreviations differ, they both refer to the same acoustic application although supplied by different vendors.

It is recommended that, wherever possible, multiple acoustic systems are completely separated and independent in all respects. For instance, this would require the use of separate and independent hull transceivers.

Owners/ operators should consider the advantages of acoustic positioning systems that have an inertial navigation input, such as the Kongsberg HAIN (Hydro Acoustic Inertial Navigation) system or Sonardyne's AAINS (Acoustically Aided Inertial Navigation System) both of which can,

• overcome the update rate limitations of speed of sound in water,

• overcome the limitations on satellite based position reference systems brought upon by poor satellite geometry.

DPOs should be aware of potential conflicts arising from operations taking place onboard their vessel and in close proximity to them. This is particularly relevant to acoustic systems being used by survey teams, BOP acoustic communications systems and acoustic frequencies used by nearby logistics or project/ construction vessels.

Note 2 (Satellite Systems) *– Satellite based systems that use a combination of signals from DGPS and GLONASS satellites provide enhanced redundancy over systems that use only a single satellite source.*

It is recommended that, wherever possible, multiple satellite based systems are completely separated and independent in all respects. For instance, this would require the use of different masts for the satellite antennae, separate cable routeing, different vendors and software. Where there is diversity of vendors and software it is recommended that the acceptance/ rejection logic is verified against the DP system manufacturer's specifications. There have been incidents in the past where diversity of vendors and software has resulted in loss of position due to the acceptance of erroneous values within the software.

Care should be taken at all times when using satellite based systems close to platforms. Guidance is given in IMCA M141, "Guidelines on the Use of DGPS as a Position Reference in DP Control Systems", which highlights potential problems when within 150m of a platform, such as the masking of GPS signals, masking of differential signals, radio interference and multipath. Good DGPS close to structures should be considered as a bonus. In these locations DGPS should not be considered as the primary position reference system.

Where multiple DGPS systems are being used, consideration should be given to set each system with a different elevation mask. This is so that any jump in position that may occur when a satellite comes into view will hit one DGPS before the next and will give the DPO some time to take action.

Owners/ operators should consider the advantages of hybrid GNSS/ IMU positioning systems, such as the Kongsberg Seatex 4D system, where an inertial input is applied to the satellite based system's position calculation. This enhancement can fill the "holes" in positioning information in extraordinary and difficult conditions that otherwise might invalidate the satellite based positioning information, such as during times of scintillation and satellite ageing.

Note 3 (Absolute Systems) - *Where three absolute systems are used it is recommended that they are based on two different principles. Only where it is impractical to use systems based on different principles should all three be of the same type. This is of particular significance where DGPS is concerned where the satellite constellation provides a source for a common mode failure.*

Note 4 (DP at non fixed Assets, e.g. FPSOs/ TLPs/ Spars) – When carrying out DP activities in close proximity to or in conjunction with floating facilities it is strongly recommended that redundant relative position reference systems are used. In these situations, a mix of absolute and relative position reference systems for station keeping is to be used only after validating that movement of the floating structure, if any, does not impact station keeping. The DPOs must be extremely vigilant when using a mix of absolute and relative position references and must be fully aware of the potential danger of diverging positioning information from both types of system.

The minimum movement referred to in the table above refers to the actual measured movement of floating facility, e.g. FPSO/TLP/SPAR. To measure this movement the DP vessel should use an absolute position reference system, such as DGPS, as the sole source for positioning information and use the relative positioning system, such as RADius, RADASCAN or Fanbeam, sited on the floating facility to measure the fluctuations in its movement.

It should also be noted that there are non-fixed offshore facilities, such as TLPs and Spars where an acoustic system, although normally considered as an absolute system, can be used as a relative system. This can be accomplished by installing the transponder/ beacon onto the submerged part of the TLP or Spar at an appropriate depth. Some TLPs and Spars are fitted with suitable subsea brackets or cradles for transponders/ beacons.

Note 5 (Absolute and Relative Systems) - When using DGPS/ GLONASS in a mix of absolute and relative position reference systems, in particular where there are two satellite based systems in a mix of three, users should bear in mind the possibility of the offshore structure blocking the satellite signals and the consequences for station keeping.

Note 6 - Wherever practical and feasible it is recommended that redundancy requirements are met by diversity of suppliers, e.g. satellite based position reference systems from different manufacturers and differential signals from different sources. This applies equally to sensors such as gyro compasses, VRUs and wind sensors.

Note 7 (Sensors) - Given the impact on heading/ position keeping it is recommended that vessels with an equivalent DP 2 class notation are provided with three gyro compasses, irrespective of the requirements of the applicable Classification Society DP rules. It should be noted that some Classification Societies, including ABS and DNV already require three gyro compasses for a DP class 2 notation.

Gyro compasses are normally fitted with a correction facility which inputs the vessel's latitude and speed. The effects of incorrect latitude or, more importantly, speed could result in a significant error in output heading. It is therefore important to ensure that the latitude and speed corrections are applied. Some systems use automatic input from GPS for these corrections. This is not recommended since there are a number of system errors that can result in undesired heading changes. It is therefore recommended to use manual input of latitude and speed.

Wind sensors are known to have suffered common mode failures, such as icing in higher latitudes, lightning, heavy rain and birds. All types of wind sensor are vulnerable, including ultrasonic types. Where ultrasonic type wind sensors are fitted, the consequences for station keeping of common mode failures, that affect these ultrasonic sensors, may be prevented by fitting mechanical wind sensors.

DP vessels are frequently fitted with sensor systems, other than heading, motion and wind, which have a potential to affect the DP system and station keeping should there be an erroneous or invalid input from them. These include draft sensors and pipelay tension sensors, where an erroneous or invalid input could result in extreme values and distortion of external forces and result in large position excursion (drive off) from the desired set point position. There should be means of preventing erroneous values from being accepted by DP. An often practiced procedure which should prevent the above problems is to input these values manually and not to rely on the automatic input function, if fitted. There should also be means of ensuring that erroneous values are prevented from being input manually.

Note 8 - Where it is anticipated that due to operational requirements the DP vessel will require to be positioned in close proximity to the non-fixed facility and where the potential for shadowing of DGPS exists, then redundancy in relative position reference sensors should be considered.

Note 9 - Where, as is normal, multiple position references are in use by DP, the DPOs should monitor the weightings closely so as to ensure that no one system or set of systems is 'hogging" the weighting. DPOs should recognise the potential dangers of using multiple satellite based systems (>2) in the suite of position reference systems and that this could result in skewed 'weighting" in favour of satellite systems at the expense of other position references. It is recommended that no more than two satellite based position reference systems be used to provide position solution as inputs into DP. Where additional position reference systems are available but not selected for use, they should, if possible, be put into monitor mode to allow for monitoring and, if necessary, for quick selection into the DP control system.

Note 10 - New or retrofitted position references are sometimes interfaced into DP through inputs designed for other position references because the DP control system has not been designed to accept them. Examples of this are pseudo Artemis or pseudo acoustics. This practice is not recommended unless accompanied by a detailed risk analysis and the residual risk, if any, is deemed acceptable. Wherever possible the displays for such position reference systems should be located in close proximity to the DP control location. This allows for quick identification and evaluation of erroneous positions.

Note 11 - The practice of connecting survey and DP is not recommended. Where it is unavoidable, galvanic isolation between the systems is to be provided. DPOs should have ultimate control over the input. All necessary precautions should be taken to ensure that the vessel's station keeping is not affected and should be addressed in the FMEA.

Note 12 (Taut wires) – Care should be exercised when lowering or repositioning taut wire weights that divers and ROVs are alerted and are a safe distance from the seabed position. Taut wire weights should also be placed clear of pipelines, manifolds or other subsea assets. These subsea assets should be positively identified prior to positioning taut wire weights, e.g. by the ROV3.10.17 It is possible for thruster wash to interact with a taut wire, acting as a strong current and causing position instability. The thruster wash could be from own vessel or from another vessel close by. DPOs should be aware of the potential for this to occur.

DPOs should be alert to the potential for taut wire weights to "skip" along the seabed and provide inaccurate positioning information. This can be avoided by ensuring that the tension control is properly calibrated and operating within specified parameters and that the angle of wire inclination is kept as near to vertical as is possible and should not normally exceed 10 degrees.

DPOs should also be aware of the potential for taut wire systems to become a "perfect" reference. This can have different causes, including the taut wire touching the side of own vessel or otherwise being restricted in its movement, or by a faulty gimbal sensor. Most DP systems will detect this fault. DPOs should ensure that the warning and alarm limits are properly set and operational.

The wires in use in modern taut wire systems are generally 5mm or 6mm in diameter. Weights are in the region of 400kg to 500kg. Taut wires are quite highly stressed for marine wire ropes and are liable to breakage, particularly at points of weakness, such as continuous wear at the spot on the main sheave, continuous wear at any guide blocks and kinks or damage caused by poor spooling or where the wire is attached to the weight. The potential for wire breakage is reduced by regular inspection of the taut wire system and by slipping and cutting (cropping) the taut wire on a regular basis.

Taut wire systems are known to suffer inaccuracies at water depths over 350m, especially in high current areas. This should be taken into consideration when planning DP operations.

Note 13 - It is important that software, parameters and values used by position reference systems are compatible with the software and acceptance criteria used by the DP control system and that this is verified by analysis and testing.

Attention is drawn to IMO MSC/Circ 645 where three MRU/VRUs are stipulated when vessel positioning is fully dependent on correct MRU/VRU signals.

Note 14 - Lightning strikes on DP vessels can cause severe and catastrophic harm to personnel and equipment. This is particularly relevant to DP MODUs and drillships operating in areas susceptible to high levels of lightning activity. Owners should assess the risks and, where found necessary, install lightning protection and surge protection equipment onboard their DP vessels. Care should also be taken that the taut wires are not fouled by other subsea lines or obstructions.

These documents can be read in full by clicking the links below:-

Construction Vessels - DP OPERATIONS GUIDANCE - PART 2 - APP 2 (Rev3 - Jan21) VESSELS

Logistics Vessels - DP OPERATIONS GUIDANCE - PART 2 - APP 3 (Rev3 - Jan21) LOGISTICS VESSELS

Note 1 (Acoustics) – The acoustic LUSBL system is not included in the above table since it is a combination of USBL and LBL in one system, where the USBL is typically used to calibrate the LBL system. Standalone USBL systems are not the norm on DP drilling MODUs.

The abbreviations, USBL and SSBL, are referred to in the above table. Although the abbreviations differ, they both refer to the same acoustic application although supplied by different vendors.

It is recommended that, wherever possible, multiple acoustic systems are completely separated and independent in all respects. For instance, this would require the use of separate and independent hull transceivers.

Note 2 (Inertial Aided Navigation) - Owners/operators should consider the advantages of acoustic positioning systems that have an inertial navigation System input to create an Inertial Aided Navigation (IAN) reference sensor. IAN input can be implemented in one of the redundant DGNSS systems or in one of the redundant acoustic position reference systems. This technique introduces the attributes of differentiation. Differentiation can reduce the risk of common mode failure.). IAN changes the characteristics of how the reference behaves and minimizes the probability of both (IAN and non-IAN) systems being rejected.

Introduction of IAN in DGNSS and Acoustic Systems provides additional robustness to position reference systems and the means to

• overcome the update rate limitations of speed of sound in water.

• overcome the limitations on satellite based position reference systems brought upon by poor satellite geometry.

• For GNSS systems this enhancement can fill the “holes” in positioning information in extraordinary and difficult conditions that otherwise might invalidate the satellite based positioning information, such as during times of scintillation and satellite ageing.

• For acoustic systems (USBL and LBL), field tests have proven that the enhancement improves the update rate to 1 hz regardless of water depth.

Note 3 (Satellite Systems) – Satellite based systems that use a combination of signals from DGPS and GLONASS satellites provide enhanced redundancy over systems that use only a single satellite source.

It is recommended that, wherever possible, multiple satellite based systems are completely separated and independent in all respects. For instance, this would require the use of different masts for the satellite antennae, separate cable routeing, different vendors and software. Where there is diversity of vendors and software it is recommended that the acceptance/ rejection logic is verified against the DP system manufacturer’s specifications. There have been incidents in the past where diversity of vendors and software has resulted in loss of position due to the acceptance of erroneous values within the software.

Care should be taken at all times when using satellite based systems close to platforms. Guidance is given in IMCA M141, “Guidelines on the Use of DGPS as a Position Reference in DP Control Systems”, which highlights potential problems when within 150m of a platform, such as the masking of GPS signals, masking of differential signals, radio interference and multipath. Good DGPS close to structures should be considered as a bonus. In these locations DGPS should not be considered as the primary position reference system.

Where multiple DGPS systems are being used, consideration should be given to set each system with a different elevation mask. This is so that any jump in position that may occur when a satellite comes into view will hit one DGPS before the next and will give the DPO some time to take action.

Note 4 (Absolute Systems) - Where three absolute systems are used it is recommended that they are based on two different principles. Only where it is impractical to use systems based on different principles should all three be of the same type. This is of particular significance where DGPS is concerned where the satellite constellation provides a source for a common mode failure.

Note 5 (DP at non fixed Assets, e.g. FPSOs/TLPs/Spars/MODUs) – When carrying out DP activities in close proximity to or in conjunction with floating facilities it is strongly recommended that redundant relative position reference systems are used. In these situations, a mix of absolute and relative position reference systems for station keeping is to be used only after validating that movement of the floating structure, if any, does not impact station keeping. The DPOs must be extremely vigilant when using a mix of absolute and relative position references and must be fully aware of the potential danger of diverging positioning information from both types of system.

The minimum movement referred to in the table above refers to the actual measured movement of floating facility, e.g. FPSO/TLP/Spar. To measure this movement the DP vessel should use an absolute position reference system, such as DGPS, as the sole source for positioning information and use the relative positioning system, such as RADius, RADASCAN or Fanbeam, sited on the floating facility to measure the fluctuations in its movement.

It should also be noted that there are non-fixed offshore facilities, such as TLPs and Spars where an acoustic system, although normally considered as an absolute system, can be used as a relative system. This can be accomplished by installing the transponder/ beacon onto the submerged part of the TLP or Spar at an appropriate depth. Some TLPs and Spars are fitted with suitable subsea brackets or cradles for transponders/ beacons.

Laser Based Systems- Laser based systems should use prisms as targets. The use of the potential higher reflectivity of prisms over other reflective surfaces provides the ability to address issues experienced with tracking of spurious targets. (By enabling setting of “rejection” thresholds.). Operations manuals should contain guidance on the use of such features in laser based systems.

Note 6 (Absolute and Relative Systems) - When using DGPS/GLONASS in a mix of absolute and relative position reference systems, in particular where there are two satellite based systems in a mix of three, users should bear in mind the possibility of the offshore structure blocking the satellite signals and the consequences for station keeping.

Note 7 Wherever practical and feasible it is recommended that redundancy requirements are met by diversity of suppliers, e.g. satellite based position reference systems from different manufacturers and differential signals from different sources. This applies equally to sensors such as gyro compasses, VRUs and wind sensors.

Note 8 (Sensors) - Given the impact on heading/position keeping it is recommended that vessels with an equivalent DP 2 class notation are provided with three gyro compasses, irrespective of the requirements of the applicable Classification Society DP rules. It should be noted that some Classification Societies, including ABS and DNV already require three gyro compasses for a DP class 2 notation.

Gyro compasses are normally fitted with a correction facility which inputs the vessel’s latitude and speed. The effects of incorrect latitude or, more importantly, speed could result in a significant error in output heading. It is therefore important to ensure that the latitude and speed corrections are applied. Some systems use automatic input from GPS for these corrections. This is not recommended since there are a number of system errors that can result in undesired heading changes. It is therefore recommended to use manual input of latitude and speed.

Wind sensors are known to have suffered common mode failures, such as icing in higher latitudes, lightning, heavy rain and birds. All types of wind sensor are vulnerable, including ultrasonic types. Where ultrasonic type wind sensors are fitted, the consequences for station keeping of common mode failures, that affect these ultrasonic sensors, may be prevented by fitting mechanical wind sensors.

DP vessels are frequently fitted with sensor systems, other than heading, motion and wind, which have a potential to affect the DP system and station keeping should there be an erroneous or invalid input from them. These include draft sensors and pipelay tension sensors, where an erroneous or invalid input could result in extreme values and distortion of external forces and result in large position excursion (drive off) from the desired set point position. There should be means of preventing erroneous values from being accepted by DP. An often practiced procedure which should prevent the above problems is to input these values manually and not to rely on the automatic input function, if fitted. There should also be means of ensuring that erroneous values are prevented from being input manually.

Note 9 Where it is anticipated that due to operational requirements the DP vessel will require to be positioned in close proximity to the non-fixed facility and where the potential for shadowing of DGPS exists, then redundancy in relative position reference sensors should be considered.

Note 10 Where, as is normal, multiple position references are in use by DP, the DPOs should monitor the weightings closely so as to ensure that no one system or set of systems is ‘hogging” the weighting. DPOs should recognise the potential dangers of using multiple satellite based systems (>2) in the suite of position reference systems and that this could result in skewed ‘weighting” in favour of satellite systems at the expense of other position references. It is recommended that no more than two satellite based position reference systems be used to provide position solution as inputs into DP.

Note 11 New or retrofitted position references are sometimes interfaced into DP through inputs designed for other position references because the DP control system has not been designed to accept them. Examples of this are pseudo Artemis or pseudo acoustics. This practice is not recommended unless accompanied by a detailed risk analysis and the residual risk, if any, is deemed acceptable.

Note 12 The practice of connecting survey and DP is not recommended. Where it is unavoidable, galvanic isolation between the systems is to be provided. DPOs should have ultimate control over the input. All necessary precautions should be taken to ensure that the vessel’s station keeping is not affected and should be addressed in the FMEA.

Note 13 (Taut wires) – Care should be exercised when lowering or repositioning taut wire weights that divers and ROVs are alerted and are a safe distance from the seabed position. Taut wire weights should also be placed clear of pipelines, manifolds or other subsea assets. These subsea assets should be positively identified prior to positioning taut wire weights, e.g. by the ROV. Care should also be taken that the taut wires are not fouled by other subsea lines or obstructions causing position instability. The thruster wash could be from own vessel or from another vessel close by. DPOs should be aware of the potential for this to occur.

DPOs should be alert to the potential for taut wire weights to “skip” along the seabed and provide inaccurate positioning information. This can be avoided by ensuring that the tension control is properly calibrated and operating within specified parameters and that the angle of wire inclination is kept as near to vertical as is possible and should not normally exceed 10 degrees.

DPOs should also be aware of the potential for taut wire systems to become a “perfect” reference. This can have different causes, including the taut wire touching the side of own vessel or otherwise being restricted in its movement, or by a faulty gimbal sensor. Most DP systems will detect this fault. DPOs should ensure that the warning and alarm limits are properly set and operational.

The wires in use in modern taut wire systems are generally 5mm or 6mm in diameter. Weights are in the region of 400kg to 500kg. Taut wires are quite highly stressed for marine wire ropes and are liable to breakage, particularly at points of weakness, such as continuous wear at the spot on the main sheave, continuous wear at any guide blocks and kinks or damage caused by poor spooling or where the wire is attached to the weight. The potential for wire breakage is reduced by regular inspection of the taut wire system and by slipping and cutting (cropping) the taut wire on a regular basis.

Taut wire systems are known to suffer inaccuracies at water depths over 350m, especially in high current areas. This should be taken into consideration when planning DP operations.

The temptation to use the taut wire system as a lifting device for alternate purposes is to be avoided and discouraged.

Note 14 It is important that software, parameters and values used by position reference systems are compatible with the software and acceptance criteria used by the DP control system and that this is verified by analysis and testing.

Attention is drawn to IMO MSC/Circ 645 where three MRU/VRUs are stipulated when vessel positioning is fully dependent on correct MRU/VRU signals

DGNSS

OVERVIEW

Global Navigation Satellite System (GNSS) is a satellite based system used to determine the geographical location of the user's GNSS receiver anywhere in the world. There are currently four fully functional systems available; the American NAVSTAR Global Positioning System (GPS) and the Russian Global 'Naya Navigatsionnaya Sputnikovaya Sistema (GLONASS), the Chinese Compass/Beidou System and the European Galileo system.

A GNSS system consists of three segments: The space segment, the control segment and the user segment. It is the user segment (i.e. the antenna and receiver) that is evident on DP vessels. A fourth segment, the reference segment, is required for a Differential GNSS system.

GPS

There are 24 satellites in six orbital planes, four satellites in each plane. The orbits are approximately 12 hourly, which means that the constellation or pattern of satellites is continuously changing from the vessel's viewpoint. New satellites are 'acquired' as others drop below the horizon.

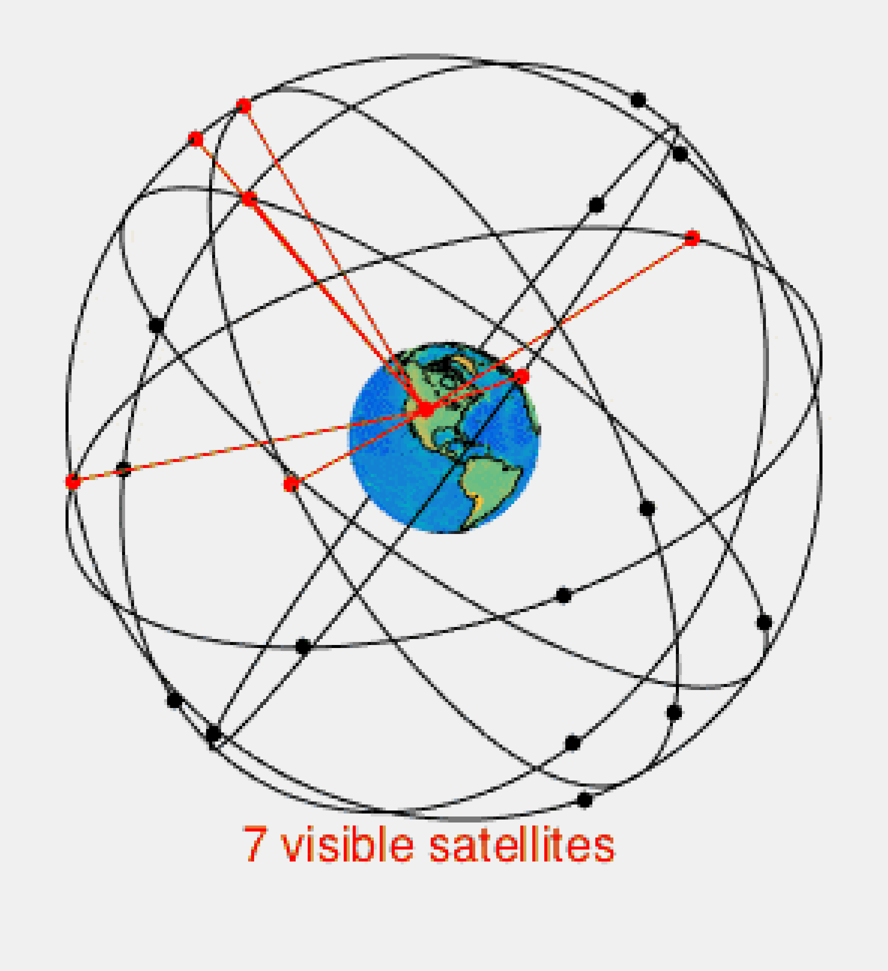


FIGURE 15 - GNSS SATELLITE ANIMATION

The vessel must have at least four satellites within its line of sight to get an accurate and reliable position. There are reasons why this might not be possible.

One is the celestial geometry of the satellites, where they are in the sky relative to the vessels position on earth and the principal here is exactly the same as when the navigator chooses which terrestrial objects to take bearing's from to fix the vessels position. If the satellites are clustered together the accuracy of the position is poor. But if the spread of the satellites is good, the position will be more accurate.

The GPS receiver calculates the position using the available satellites and depending on the geometry calculates for the user a Horizontal Dilution of Precision figure or HDoP figure to help indicate to the DPO how ACCURATE the GPS position may be. HDoP figures range from 0 to infinity; If the HDoP figure is 3 or more the GPS position may not *be accurate enough* for DP purposes.

Most modern GNSS units are capable of using several constellations and hence this is less of a problem. A more reliable measure of the quality is the Standard deviation and/or the receiver assessment of its own accuracy.

The results we obtain from Raw GNSS are not particularly accurate. There are errors in the clocks, the orbit, signal delays through the ionosphere and troposphere, possible multipath reflections and the receiver we are using. To mitigate these effects the receiver needs a correction service.

The basic types of correction are:

Differential – this is where there is a ground station reasonably close to where our receiver is working. The principle is that the signals from each satellite to both the ground station and our antenna will experience approximately the same errors. When we use the data to calculate the position of the ground station we can detect the gross errors as we know the position. It is this data that is sent to our receiver which assumes roughly the same errors. The further our receiver travels away from the ground station the less applicable are the corrections.

Orbit and clock or (Precise Point Positioning (PPP)– the network of ground stations are monitoring each satellites orbit and clock errors and this data is sent to out to the receiver as part of the correction data. Added to that the satellites are transmitting their signals on two distinct frequencies. They leave the satellite at exactly the same time but arrive at our receiver as slightly different times as the frequencies are delayed by ionosphere and troposphere by a different amount (similar to white light in a prism being split into the colours due to the differing frequencies). The receiver uses a mathematical model to assess the actual delay and hence, with the orbit and clock information, the position calculation becomes very accurate (5-10 cm) worldwide.

Most corrections are delivered from the 'Inmarsat' geo stationary satellites which can be a problem in high north south latitudes, but they can also be delivered over the internet (only recommended as a backup if all else fails), and also one provider is using Iridium whose satellites are in a low earth orbit and has truly global coverage.

Link to C-Nav video using Iridium rather than Inmarsat

https://www.oceaneering.com/positioning-solutions/positioning-products-and-services/

OPERATIONAL & FAILURE CONSIDERATIONS

In higher northern latitudes the geo-stationary satellites (Inmarsat delivering correction data) will be in orbit to the south of the vessel. If the vessel is working on the north face of a large structure the satellites may not be visible to the GPS receiver. In this case the Corrected GNSS position may drop down to a raw uncorrected position and be rejected by the DP system. This is one reason to ensure that different GNSS receivers are using different satellites for the correction data.

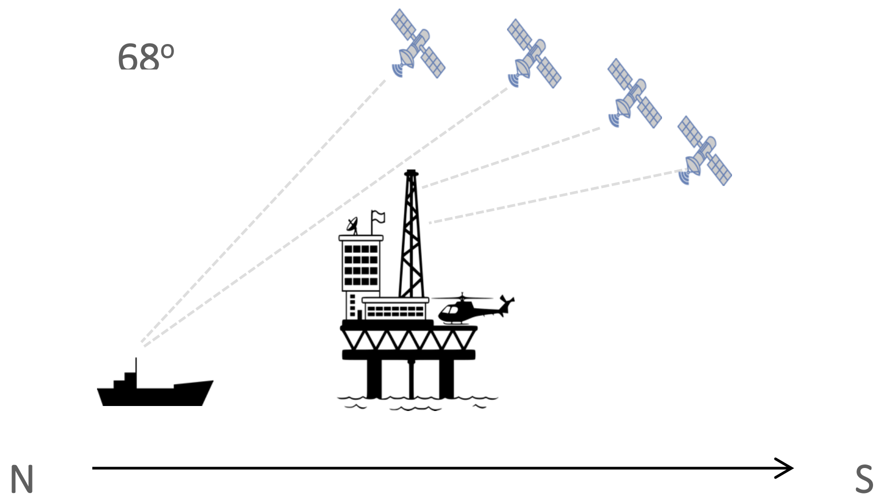


FIGURE 16 - GNSS CORRECTION FROM GEOSTATIONARY SATELLITES

The opposite is also true if working in very southern latitudes where the geo-stationary satellites will appear north of the vessel.

Large structures such as offshore platforms can create another issue for the GPS system here. The signals sent from the satellite may bounce off the structure and will arrive at the vessel by a non-direct route. This is common when the structure rises above the GPS antenna. The extra time the signal has now taken to reach the vessel means that the pseudo range will be wrong and the resultant position will not be accurate. These errors known as multi-path error.

In the picture we can see the direct path in solid line and a reflected path in a dashed line

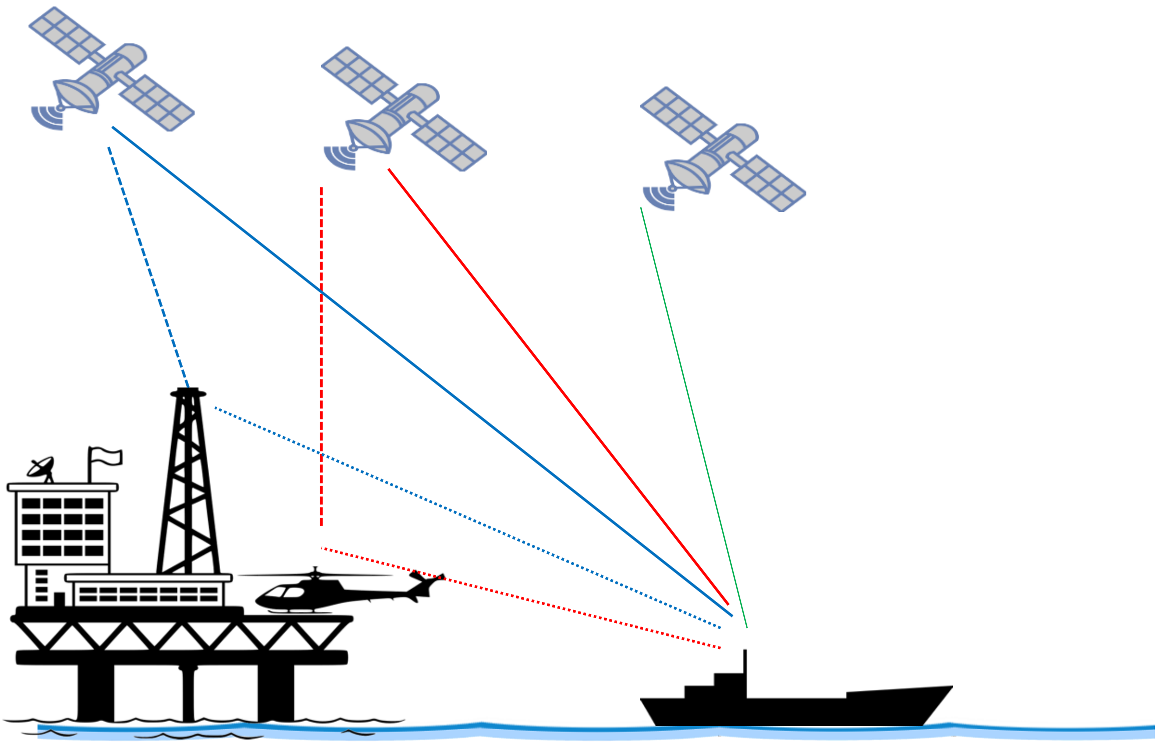


FIGURE 17 - GNSS MULTIPATH

Another consequence is that both the direct and the reflected signal arrive and interfere with each other. If there are plenty of satellites in view and enough ranges are received correctly then the 'bad' ones are not needed for a solution.

Note also that the satellite orbits are not exactly circular and vary somewhat and the atomic clocks drift due to relativity (as predicted by Mr Albert Einstein!)

The satellites are in constant communication with the ground control centres that are equipped with even more accurate atomic clocks. This means that the ground stations can calculate exactly where they are in time and space. In and Orbit and clock solution the ephemeris (the coordinates of the satellite) and the clock error are transmitted to the vessel receiver as part of the correction data.

When using a Differential solution, the codes arrival time from each satellite are determined using the clock on the vessel receiver (which is not an atomic clock!) and then using at least 4 satellites a pseudo range is calculated and the receiver solves for position (3 unknowns x, y and z) and also the error between the receiver clock and the real time. It takes time for the correction to be observed by the local reference segment, sent to the network hub, and then transmitted to the vessel via IMARSAT, this time lag is known as Age of Data (AoD). AoD can affect the accuracy of the GPS position considerably. If the AoD is up to 6 seconds the data is relatively recent and DGPS can be used as a DP PRS.

Typical GGA message string below with the data fields separated by commas

$GPGGA,172814.0,3723.46587704,N,12202.26957864,W,2,6,1.2,18.893,M,-25.669,M,2.0,0031*4F
0 , 1 , 2 ,3, 4 ,5, 6,7, 8 , 9 ,10, 11 ,12,13, 14 *15

NOTE – The data string exceeds the NMEA standard length.

GGA message fields

Field	Meaning
0	Message ID $GPGGA
1	UTC of position fix
2	Latitude (ddmm.mmmmmmm)
3	Direction of latitude: N: North S: South
4	Longitude (dddmm.mmmmmmm)
5	Direction of longitude: E: East W: West
6	GPS Quality indicator: 0: Fix not valid 1: GPS fix 2: Differential GPS fix (DGNSS), SBAS, OmniSTAR VBS, Beacon, RTX in GVBS mode 3: Not applicable 4: RTK Fixed, xFill 5: RTK Float, OmniSTAR XP/HP, Location RTK, RTX 6: INS Dead reckoning
7	Number of SVs in use, range from 00 through to 24+
8	HDOP
9	Orthometric height (MSL reference)
10	M: unit of measure for orthometric height is meters
11	Geoid separation
12	M: geoid separation measured in meters
13	Age of differential GPS data record, Type 1 or Type 9. Null field when DGPS is not used.
14	Reference station ID, range 0000 to 4095. A null field when any reference station ID is selected and no corrections are received. See table below for a description of the field values.
15	The checksum data, always begins with *

FIGURE 18 - GGA NMEA MESSAGE STRING

For Differential corrections, consideration also needs to be given to the distance of the reference stations in use from the vessels position. If the reference station is over 400 miles away then the path from the GPS satellite to the reference station is becoming considerably different from the path to your receiver and so the corrections are less applicable to your location. This has the effect that the further away the receiver is from the base station the less applicable is the correction data.

GPS data can be severely corrupted of even destroyed by SOLAR activity. The maximum and minimum activity (manifest by the number of sunspots and the disturbance of the suns magnetic field) repeats on an 11 year cycle. The last large solar activity was in 2013/14 and it was not unusual to lose ALL GPS data for up the 12 hours in equatorial regions. The manifestation can be an initial slow drift, which may affect all the GNSS receivers but then a complete loss of signal and hence position. The use of multiple frequency transmissions has improved the situation, but DPOs need to be aware that this is a possibility.

The solar activity also creates Solar mass ejections and when these increase, here on earth we experience much more activity around the northern and southern lights.

Click to simple explanation.

The Various GNSS Systems (constellations) are owned and managed by Governments. They are made available free of charge but can be severely downgraded even switched off.

GPS – USA

GLONASS – Russia

Beidou – China

Galileo – European Union

ADVANTAGE, DISADVANTAGE

Advantages	Disadvantages
GNSS is available world-wide continuously	Potential high HDOP errors (using GPS only)
GNSS is free of charge	Differential services must be contracted and paid for
GNSS is a globally referenced system (Datum WGS 84)	Loss of data and/or differential corrections close to nearby structure
The Vessel equipment is (relatively) low-cost and simple to operate	Possible multi-path problems exist close to platform or other structures
DGPS is of sufficient accuracy for DP PRS (~1m)	Poor quality of positioning during periods of high solar activity
PPP (Precise Point Positioning) is capable of decimetre accuracy	

LESSONS LEARNT FROM DP EVENTS

TECHOP (D-06 - Rev1 - Jan21) DGNSS POSITION REFERENCE SENSORS states that,

> *A significant number of DP incidents relate to position reference system issues and Differential Global Navigation Satellite System (DGNSS) problems in particular. Origins include configuration problems, external common cause failures affecting multiple DGNSS receivers, as well as a lack of separation, independence and diversity between DGNSS receivers, which permits internal common cause failures to defeat redundancy.*

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Event Bulletin 04/17 October 2017	Common mode failure of DGNSS – DP undesired event
IMCA DP Station Keeping Event Bulletin 02/17 June 2017	Loss of DGNSS resulted in ROV being recovered – DP incident
IMCA DP Station Keeping Event Bulletin 02/17 June 2017	Bad connection causes loss of DGNSS – DP observation
DP Event Bulletin	Case Study – Masking of PRSs – SIMOPS

01/22 – April 2022	

NEW DEVELOPMENTS IN LAST 5 YEARS

In 2020 IMCA released M 252 Rev 01 Guidance on position reference systems and sensors. This document offers operational consideration summaries for each PRS.

For GNSS – Operational considerations;

Subject	Operational Considerations
The use of Dual GNSS	When using a dual DGNSS package, two receivers are essential; to avoid the possibility of a common mode of failure it is recommended that different models and software are used. Ideally the equipment would be from different manufacturers. Two fully independent differential links should be used and ideally should be based upon different transmission media e.g. Inmarsat and High Frequency (HF). Each receiver should be able to use more than one correction link so that operations can continue if there is a failure of a link and/or hardware or power supply. The connections between the receivers and the DP system should also be fully independent. If computers are used within the solution, then full computer hardware redundancy (i.e. a third PC) should also be considered to improve uptime. The DGNSS units in a dual set-up often use the same satellites; however, use of satellites from different systems can provide a degree of independence. DGNSS systems in dual configuration should not be selected on a primary and secondary system basis, but both should possess comparable performance.
Keelson Clarification	Inmarsat is the company that operates the geo-stationary satellites that are used to transmit most corrections to the user receiver. The cost of transmission of the correction data was linked to the power required, so several of the satellites transmitted on less powerful and wide cone of transmission, but this required a dish antenna pointed at the transmitting satellite. This was referred to as an Inmarsat system. This arrangement allowed the GNSS to pick up the correction data from the Inmarsat system via a demodulator and use it to calculate a position. There were other satellites that provided high-power transmission, but to achieve the higher power the 'beam' was more focussed and directional, and this was referred to as 'Spotbeam'. As it was higher power the receiving antenna did not need to be directional (omni directional) and this again was fed through a demodulator and into the GNSS unit. For some time now all the geostationary satellites transmit on high power so there is no need for the Inmarsat receivers (though they still work!) Many of the more modern GNSS receivers now have a single antenna that captures the constellation data AND the correction data and generally they do not have external demodulators. Some receivers and GNSS suppliers are using Iridium (low earth orbit satellite system) where the distance to each satellite is much smaller and hence the signals will be stronger. Several suppliers also provide the data over the internet and this could be considered as a last resort back up as the route of that data is not in the control of the correction supplier. In several fields around the world the oil major provided a dedicated correction service, Petrobras and Brazil used UHF, the North sea used HF, but these systems are not in use anymore. The modern receivers are capable of using all four of the main system (GPS, GLONASS, Galileo and Beidou) so lack of satellites is becoming less of an issue. Also, the use of dual frequency transmissions has improved accuracy, initially the second frequency (L2) was a very weak signal but that is changing now.
The use of Dual GNSS	If three position references are being used and comprise a dual DGNSS installation plus one other position reference, then simultaneous failure of both DGNSS has to be considered. Both DGNSS systems can be subject to common drift. This could make it appear that the third system is at fault as it would appear to drift away from both DGNSS positions. This is particularly valid if reliability is reduced e.g. due to poor satellite coverage.
Keelson Clarification	Slow drift of two GNSS systems is very difficult for a DP system to detect. This tends to be a problem in the magnetic equatorial regions at certain times of the day when solar activity is occurring (it would normally manifest as a slow drift and then it would fail completely). If a vessel is working is these areas then it would be sensible to use 4 references, recognising that the location and operation can make that a challenge. For open water then 2 x GNSS and 2 x acoustics may be the only solution or if it is supply close to platforms then a laser and a radar would be sensible. Owners of vessels need to be proactive to ensure the vessel is equipped with appropriate reference systems
Satellite Antennas	Satellite antennas should always be sited in optimum locations on the vessel and, in dual DGNSS, also suitably separated. Therefore, if one is masked from satellites or damaged through local activity the other should still be operational. If an Inmarsat-based service is used, then a dedicated Inmarsat reception unit should be considered. If two Inmarsat links are used and more than one Inmarsat terminal is available, the DGNSS correction demodulators should be connected independently to both terminals.
Keelson Clarification	Please see comments previously made regarding Inmarsat.

Satellite Antennas	If optimum satellite and differential antenna locations cannot be occupied, the DGNSS user should be aware of, and realistic about, the DGNSS performance limitations likely to result. The elevations and relative directions on which satellite or differential signals will be affected by obstructions or other transmitters should have been noted after installation. This will help to mitigate the effects of antenna locations which are less than ideal. Every effort must be made to make at least one DGNSS available at all times when two are installed.
Keelson Clarification	This is more an original design issue, unless the GNSS units are being replaced by more modern units. If, however there are known directions of obstructions then these should be considered in the Operation Risk analysis
Differential Service Selection	Services and correction links which suit the vessel's known and potential work programme (e.g. DGNSS service coverage and performance) should be selected. Users should ensure that the correction data is not outdated.
Keelson Clarification	Not only Differential but all correction services
Reference Station Selection	With any single DGNSS service which has several reference stations, the optimum station(s) should be selected based on the following criteria: • Distance from mobile to reference station (validity of corrections and range from transmitter should be considered); • Direction to transmitter (potential obstructions should be considered as direct line of sight between vessel antenna and transmitter is required); • Reliability of reference station (i.e. does it have a proven track record?); • Intervention i.e. how easily and quickly can the service provider visit the station to remedy a fault? • Availability of back-up reference station(s).
Keelson Clarification	If you are using Differential corrections this advice is valid. Note that for many years IALA was considered a useful free service with limited range as it was transmitted on medium frequency. But the veracity of the data left a lot to be desired and in the writer's opinion should not be relied upon for DP operations.

For GNSS Failures;

Effect	Cause	Mitigation
Interruption to satellite tracking	Multipath or obstructions to antenna such as when working close to platforms or other structures.	During installation ensure antennas have clear line of sight to the sky. At mission planning stage check whether obstructions will impact performance. Consider use of multiple GNSS systems to provide additional satellites (e.g. GPS and GLONASS).
		It is unusual for a modern GNSS to end up with less than four satellites, but some operations may severely limit the view of the sky. Many GNSS systems can also predict the satellites that will be available over a period of time.
Radio-frequency interference (RFI)	Transmitting devices such as data or video telemetry systems or satellite communication systems (e.g. VSAT, Sat-C) interfering with GNSS and satellite correction delivery system.	Antennas should be installed at the maximum distance from other radiating antennas (IMO recommendation 3m separation from other radiating sources). Ensure antenna cables are terminated correctly and outdoor connections are sealed with suitable waterproof tape. During installation and commissioning it is important to conduct comprehensive tests to identify any sources of RF interference. During maintenance visits, check cables and connectors for damage, cracking and water ingress – replace if necessary.
		This can happen in service if a new antenna is installed for some new item. MoC should ensure that when the new item is tested that the DP and all its inputs are active to try check for any RFI

Ionosphere – position bias in single frequency systems	Failure of ionosphere-model to cancel out the effects of ionosphere delay in single frequency systems. Typically occurs during periods of increased ionosphere activity.	Use GNSS receivers to calculate true ionosphere delay error and an augmentation service that can remove ionosphere delay error to cancel this effect. The use of dual frequency receivers is recommended.
		A single frequency receiver needs to use a model for the ionospheric delay. Be sure you know what your GNSS receivers are based on (single / dual frequency etc)
Ionosphere – scintillation	Causes rapid fluctuations in the phase and amplitude of the L-Band satellite signal as it passes through small-scale irregularities in the ionosphere. This can cause the receiver to lose lock to the GNSS satellites and also the L-Band augmentation satellite link. The effects of scintillation appear in different localised regions of the sky and thus only affect certain satellites at a time.	If scintillation is detected it may be necessary to disable the particular satellite that is causing problem. Ensure redundancy in delivery of augmentation data (i.e. from different satellites and/or terrestrial broadcast). When possible, use multiple DGNSS reference stations and/or a precise point position (PPP) augmentation solution. Consider use of multiple GNSS systems to provide additional satellites (e.g. GPS and GLONASS).
		This can affect the GNSS top the point the system ceases to function. Ensure you have other forms of Position reference systems available if working in locations where this can happen.
Loss of correction data	Failed correction data link. Failure of reference station(s).	Ensure redundant and diverse correction links. Ensure reference stations have redundant equipment and communications links. Use multiple reference stations, where possible, or use a PPP augmentation solution.
		It is extremely unlikely that the delivery from the satellite will fail, however the receiver can lose the data (if the SNR is low etc) ensure that different receivers are tracking different satellites
Change of reference station or station combination used affecting position accuracy and redundancy	Incorrect/inappropriate selection of reference stations or vessel/vehicle has moved to new work location	Ensure selection of appropriate reference stations for work location (DGNSS) or use a PPP solution. Changes to system configuration should be formally recorded (preferably in a change management system).
		Most modern systems will replace a ‘Diff’ station if the vessel has moved, BUT this may be a configuration setting so the DPOs should be aware of how they are set up.
Poor satellite geometry or insufficient number of satellites.	Elevation mask change.	Ensure elevation mask is set to a value such that stable tracked GNSS satellites are available for the position solution (typically between 5º and 12º). Changes to system configuration should be formally recorded (preferably in a change management system).
		Sound advice
	Satellite masking caused by obstructions.	At mission planning stage check whether obstructions will impact positioning performance. Consider reducing (if possible and without further degradation) the elevation mask to include additional satellites. Consider use of multiple GNSS systems to provide additional satellites (e.g. GPS and GLONASS).
		If the vessel is going to have a restricted view of the sky then ensure other appropriate references are used as well
	Satellite de-selection – normally satellites are automatically flagged as unhealthy but occasionally the user may disable a particular satellite.	Ensure that only problem satellites are de-selected and when problem has cleared satellites should be re-introduced. Changes to system configuration should be formally recorded (preferably in a change management system).
		If a satellite has been manually blocked ensure this is recorded in the DP logbook and identified at the Watch handover etc. It will need to be ‘unblocked’ at some stage.
		Monitor system performance and official warnings if available for any signs of degradation.

	Changing constellation availability due to unhealthy satellites or satellite manoeuvres.	Consider use of multiple GNSS systems to provide additional satellites (e.g. GPS and GLONASS).
		This was a consideration some years ago when GLONASS was not being maintained, however all four major systems are now fully maintained and unless some geopolitical issues arise access should be maintained.
Loss of GNSS signal	Intentional signal jamming can occur when certain bodies (e.g. regulatory or military) conduct jamming trials. Intentional signal jamming can also occur if military forces are operating near to work location or if the user is operating close to military installations	Regulatory bodies will normally, but not always, issue notifications of where and when jamming trails are undertaken. Users should check notifications to see if work location is affected. User should monitor systems if military forces or installations are nearby for any signs of degradation in positioning.
		Often the military will issue warnings but always be sure that DP is not ONLY supported by GNSS.
	Un-intentional signal jamming is typically caused by RF interference from other transmitting devices – for example, re-radiating GNSS, microwave transmission links on offshore platforms, and military radar.	Conduct tests to discover source of interference by: - Systematically switching off transmitting devices; - Check antenna, cabling junction boxes for signs of damage, degradation or water ingress and repair if necessary. If working close to installations (e.g. offshore platforms) check for any transmitting communications devices such as microwave links which can cause interference.
		This was covered under RFI above
Equipment failure	Failure of hardware including GNSS receivers, correction receiver, PCs. Issues with software not operation or suffering corruption. Damage or degradation in condition of antennas and cables.	Ensure that there are a minimum of three position reference systems active within the DP system based on at least two different principles and suitable for the given operating conditions, as per IMO MSC/ Circ.645 6 June 1994 / MSC/ Circ.1580 16 June 2017. Have 100% spare equipment available including software installation files. Ensure all configurations, where possible, are backed up. Conduct regular inspection and maintenance to mitigate potential problems occurring.
		If you are holding 100% spares on board, I would have thought it would be better to have it installed and running so there is no outage period if one fails?

PRACTICAL ONBOARD EXERCISE

Look at your current vessels FMEA, and DP Operations manual and ASOG. Do your current operating conditions offer any restrictions to the use of DGNSS as a position reference system?

MTS TECHOP (D-09 - Rev1 - Jan21) PRS AND DPCS HANDLING OF PRS offers the following tabulation of GNSS position refence system mapped against their seven pillars philosophy. Consider this with reference to your current vessel's FMEA

	Autonomy	Independence	Segregation	Differentiation	Fault Tolerance	Fault Resistance	Fault Ride-Through
Definition	• Start up on application of power and begin to output best possible position data. • Report error and integrity to DP.	• Not subject to a common mode of failure with other PRS.	• Good physical separation between GNSS equipment intended to provide redundancy.	• Diversity of equipment.	• Ability of a GNSS to continue in operations following a single failure (high probability failures).	• Not susceptible to failure.	• Continue in operation during transient conditions.
Compromised by	• Loss of configuration on power loss. • Need for operator to enter settings on startup. • Potential for erroneous inputs by operator. •	• Common power supplies. • Ionospheric phenomena. • Effects of shadowing. • Lack of diversity in corrections. • Lack of diversity in constellations. • Common HMI if not well designed. • Choice of interface protocol which may restrict use of available and relevant data.	• Lack of attention to spatial separation. • Inadequate attention to siting requirements. • Lack of lightening protection. • Proximity to other RF sources. • Poor mast design.	• Lack of alignment on a uniform interface protocol. • Lack of transparency in internal computations. • Increased complexity in handling of PRS by DPCS.	• Requirement for operator intervention. • Unwarranted operator intervention.	• Poor installation. • Lack of suitability for marine environment. • Erroneous configuration settings. • Lack of preventative maintenance. •	• Lack of ride through capability for loss of GPS signals. • Lack of ride through capability for loss of correction signals. • Ride through capability ignored by DPCS (Fail back to lower precision solution).

Mitigated By	• Retention of configuration settings by design. • Switch automatically from Differential solution to PPP (on start-up). • Alarm at DP system. • Multi-reference solutions providing higher integrity.	• Segregation of power supplies in line with redundancy concept. • Choice of equipment (dual frequency receivers, capability to received multiple constellations). • Diversity if differential corrections and modes of transmission. • HMI designed to preserve independence.	• Following OEM recommendation on antenna siting. • Suitable lightening protection. • Good mast design.	• Systems engineering approach. • Alignment between PRS vendors and DPCS vendor on interface protocols. • Robust and transparent objective driven verification and validation processes.	• Ability to swap automatically between correction sources or multi-reference solution Note: Multireference solutions can provide higher integrity position reference data with the required accuracy for station keeping applications. • Automate functions to the extent practical.	• OEM installation requirements adhered to. • Type approval of hardware. • Control of access to configurable settings. • Focus on preventative maintenance (Example antenna cable and connection inspection / replacement).	• Resilient to short term outages of GPS. • Resilient to short term outages of corrections. • Alignment between PRS and DPCS vendors on interfaces • Inertial aiding.
GNSS	• **Remarks**	• Suitability of raw, differential or PPP solution dependent on industrial mission. • Transparency of solution type being output to DPCS (not used by DPCS). • The limitations of single frequency receivers to be clearly understood. • Impacts of regional / geographical vulnerabilities (Example – Scintillation) on industrial mission to be taken into consideration and may result in augmentation of PRS requirements. • Consideration in critical sparing of equipment (susceptibility to lightening damage). • Surveying offsets and recording same. • Validation and verification of offsets. • Stringent MOC processes to be applied (relocation / installation of equipment, firmware and software updates). • Be aware of the potential pitfalls of diversity leading to compromising overall system performance. • Evaluate the need for introducing diversity when not significantly enhancing integrity of PRS solution. • Diversity achieved by choice of degradation of solution is not recommended (Example single frequency receivers). • Minimise need for operator intervention. • Minimise potential for inadvertent and unwarranted operator actions. • Compromising siting requirements introduces vulnerability to faults. • Reported incidents caused by resonance due to mast design. • Alignment on interfaces is crucial for confidence in PRS handling. • Firmware updates by component / equipment manufactures not communicated to PRS manufactures resulting in changes to performance or functionality.					

GNSS Aided Inertial	• The primary objectives of GNSS aided Inertial is to deal with short term outages of GNSS signals, periods with reduced GNSS availability, fewer GNSS satellites, reduced geometry, integrity check of GNSS data, enhanced RAIM capabilities and short term outages of correction signals etc. • Increased integrity level of non-differential GNSS systems. • Diversity in principle of PRSs negates the need for inertial to provide ride through capability for extended outages. • Has the ability to provide independent velocity, heave, roll, pitch and heading information. • Can be used to enhance resilience for short term outages of GNSS and correction signals. • Loss of inertial should not result in loss of GNSS PRS.
Dependencies	• Time Stamp. • Heading Input - Heading data is used for transforming position to reference point. • Attitude - VRU may be used for applying attitude information to offsets. • Note: Default position reported is antenna position.

LASER

OVERVIEW

Laser Systems are relative position references. They do not give global coordinates. They give a range and bearing to a reflector placed on an object nearby. In most cases this will be a fixed position, however, some cases they can be used to give a relative refence against a moving target such as a shuttle tanker engaged in offtake operations, or from an FPSO or Pipelayer etc.

Most Laser systems have two components.

1. a projector/scan unit which is situated on the DP vessel in a place with an uninterrupted view of the horizon.
2. A reflective target that must be placed on a target object such as a nearby platform or FPSO etc.

The projector/scan unit sends out a laser beam of white light. The laser beam hits the reflective target and is reflected back towards the projector/scan unit. The projector /scan unit will have been scanning the horizon and will detect the reflected laser beam. The unit can then use the time lapse of the reflected laser and the relative azimuth of the reflector to calculate the range and relative bearing of the DP vessel to the target.

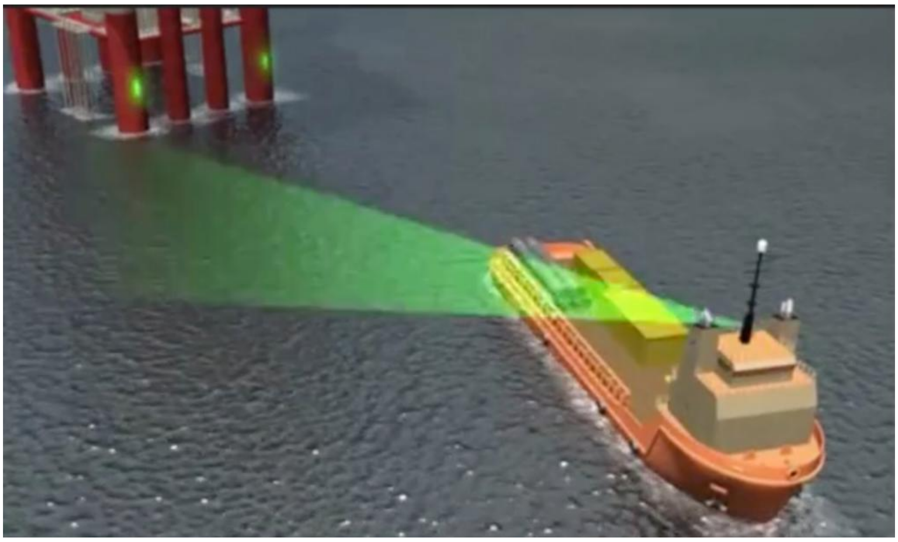


FIGURE 19 - LASER SHORT RAGE MEASUREMENT

Laser position reference systems operate on simple principles, are relatively low cost, and once they have been set up with the correct targets identified they run automictically and give an accurate range and bearing to 0.5m and 0.5°. There are however some things that a diligent DPO should know and be mindful of when choosing a laser system as a position reference system for DP and when operating in DP mode with a laser system selected.

OPERATIONAL & FAILURE CONSIDERATIONS

Firstly - Lasers must be manufactured to meet 'eye safe' ratings which means the laser power is limited. This limits the range of operation of a laser position reference systems to between 1k to 250m depending on the manufactures specifications and the targets being used. This may be less if environmental conditions deteriorate, if it rains, if the target gets wet and in reduced visibility due to fog/snow. The MTS have a paper explaining the impact of Reduced Visibility Conditions on Laser-Based DP Sensors.

Secondly - The laser targets must be kept clean otherwise the laser light will not be reflected, or the range of operation will be reduced. This may mean that the crew of the DP vessel need access to the platform to rig or to clean permanently rigged targets to clean them. The DP vessel may keep its own targets on board and deploy them on arrival at the site. This means that the system is not available for arrival and that the crew of the DP vessel still need access to the Rig/Platform in order to deploy. This can be time consuming as permissions and access is arranged but is essential. Alternatively, crew on the platform can be assigned to clean the targets. The DPO should be certain that the task will be performed adequately before delegating. Remember that IMCA M103in the DP Location Set-up Checklist section states that

> *The purpose of these checks is to ensure that the vessel's station keeping performance at the working location is satisfactory and, in particular, to ensure that the position reference system is properly set up.*

Thirdly the positioning of the target on the platform or object is critical. There must be a direct line of sight between the projector/scan unit and the target. IF the target is placed near a walkway or area of heavy foot fall the laser system may suffer from 'Seduction of the signal link'. This is where the scan unit picks up on fixes on the refection of a person walking past the target, this is made all the more likely as the platform crew will in reflective high vis clothing.

The DP vessel must make it clear to the platform crew that the placing of the target in an appropriate place is critical and DP operations should not commence unit the DPO is satisfied with the location of the target.

IMCA M103also reminds us that

> *"The risk that radar or laser range-finding position reference instruments may have the line of sight with their target obstructed by the lift should be analysed and mitigated;*

And finally, remember that laser system uses the relative azimuth of the reflector to calculate the relative bearing of the DP vessel to the target. The vessels heading is then used by the DP system to calculate the vessel position. This means that the overall accuracy of the laser system position is dependent on the accuracy and stability of the gyro compass.

You will remember that IMO 1580 3.4.3 Position reference systems tells us that :

> *.6 The performance of position reference systems should be monitored warnings should be provided when the signals from the position reference systems are either incorrect or substantially degraded.*

Content vigilance is needed at all times.

ADVANTAGE, DISADVANTAGE

Advantages	Disadvantages
Quick and simple to set up and operate	Limited range capability
High accuracy	Line-of-sight requirement
Low-cost system (tape targets)	Degradation of signal when lenses and/or reflectors are not clean
Easy to site the targets (Hazardous Areas)	Will suffer in poor visibility conditions
Targets are not powered	Can be affected by low, bright sunlight close to target line
	Prism targets are expensive

Note that the useable range is totally dependent on the targets and the angle of incidence. The tape targets (flat or cylinder) can be as little as 150 to 200m. It is vital that before any operation is undertaken that the locations of any targets are analysed to ensure they will be suitable. For the Prism reflectors the range can increase to >1000m.

The DPO needs to set up the system and identify the correct target. If a single target is used and the target is lost for any reason it may not automatically re-acquire and send a fix to the DP without the DPO intervention. When using multiple targets if one is obscured, when line of sight is resumed the laser will recognise the target from its relative position to the others.

LESSONS LEARNT FROM DP EVENTS

2022	
DP Event Bulletin	ITEMS
02/22 – August 2022	Relative PRS – A Reflection

NEW DEVELOPMENTS IN LAST 5 YEARS

In 2020 IMCA released M 252 Rev 01 Guidance on position reference systems and sensors. IMCA M 252 offers the following tabulation of Laser position refence system mapped against operational considerations.

Subject	**Operational Considerations**
Equipment Selection	There are a number of different manufacturers of laser position reference equipment in the market, each solution having slightly differing characteristics for specific mission applications, for example, operating range or accuracy. The components that make up the laser reference system are a mix of passive and active components and therefore different operating and maintenance considerations apply compared to those reference systems with only passive components. In addition to the vendor selection, other considerations might include: • DP operating range – the range is typically shorter than other relative reference systems for example microwave radar; • Desired number of and type of reflectors located on the fixed asset (different reflectors offer different range capabilities and increased numbers of reflectors can improve the reliability of the reference); • The environment in which the vessel will be operating (as this technology is based on line of sight, the operating range is greatly reduced in fog, snow and heavy rain).
Keelson Note	Range is dependent on the target and other factors. BUT if prisms are used the accuracy at long range is better than the accuracy of short range radar devices (i.e. not Artemis) Use of multiple targets can depend on the scanner being used, and the interface to the DP
Sensor Placement (vessel)	Sensor (scanner) placement varies with each application, therefore it is important to consider the specific application in conjunction with the manufacturer of the sensor. The scanner should be installed in an area that allows 360-degree rotation and has easy access to allow for routine maintenance and servicing. The mounting location should avoid areas where high vibrations are experienced and be away from sources of dust, smoke, water spray or radiant heat to avoid degrading reference performance. It has been found that the ideal place to install the scanner is on the vessel's centre line directly above the bridge. It is essential that the scanner be positioned to give a clear line of site in all directions where targets are to be installed. Some operators may require more than one mounting point on a vessel for task flexibility.
Keelson Note	The placement of the Sensor is normally associated with the 'working area' relative to the target vessel, so on PSVs it tends to overlook the aft deck, but Shuttle tankers it is generally fwd and for accommodation / walk to work it could be around the gangway area.
Target Placement	There are two main types of targets, reflective tape and retro prisms. Care should be taken to mount both types of target vertically. This is particularly important with vertically stacked prisms for longer range use. Poor targets are harder to track, and this increases the chance of picking up spurious targets. • Reflective tape – only tape targets from laser PRS equipment manufacturers should be used. The condition of the tape target should be monitored, and should degradation occur the target should be replaced. Targets made from tape will generally give ranges up to 150 metres depending on conditions. It is recommended that targets be cylindrical, to allow viewing from all angles, 150mm in diameter, but not exceeding 250mm, and 1000mm in length.

	• Retro prisms are required for longer ranges. A single prism will give reflections from +/- 30-degrees either side of the prism centre line. For 360-degrees working, a minimum of 8 prisms are recommended. For ranges over 1000 meters prisms may wish to be stacked for more robust tracking. • The use of retroreflective prisms where possible should be encouraged. • Targets should be sited with consideration of the line of sight between the sensor and the target throughout the entire DP operation. • In addition to direct line of sight considerations, also bear in mind the operation itself. For example, crane operations may pass through the area and interrupt the tracking lock.
Keelson Note	Often targets belong to the vessel and require to be delivered before and recovered after the operation. Some field operators site targets on their assets to reduce this time and improve efficiency.
Target Less System	With no targets to deploy the system is ready for immediate use when entering the work area. The system relies on structures that provide a changing profile therefore reliance may not be possible given high straight sided assets. Ensure that the system has the correct size set for the vessel and correct offsets. Returns inside the envelope of the vessel are ignored by the tracking algorithm.
Keelson Note	This is a fairly recent technology to be deployed. There is little practical information available at this stage. Hopefully some case studies could be shared by users going forward.

For Laser Failures;

Effect	Cause	Mitigation
Interruption of laser beam	Signal blocked by obstructions or a dirty sensor lens.	Contingency planning of site and work requirements. Good communication with the asset hosting the targets to ensure they are not interfered with or obstructed. Ensure lens is kept clean.
Keelson Note		Also consider if low sunlight / rain / fog may affect the path to/from the target
Reduction in operating range	Operating range is greatly reduced in fog, snow and heavy rain.	Contingency planning through receipt of good weather forecasts.
Keelson Note		Consideration to use alternative relative reference of a different operating principal
Acquisition of a false target	Bright reflections in close proximity to system targets.	Optimum performance requires the use of the manufacturer's own targets.
Keelson Note		Also consider using multiple targets, such as prisms, as the laser system can calculate their relative positions and is less likely to pick up on false targets.

PRACTICAL ONBOARD EXERCISE

Look at your current vessels FMEA, and DP Operations manual and ASOG. Do your current operating conditions offer any restrictions to the use of Lasers as a position reference system?

MTS TECHOP (D-09 - Rev1 - Jan21) PRS AND DPCS HANDLING OF PRS offers the following tabulation of laser position refence system mapped against their seven pillars philosophy. Consider this with reference to your current vessel's FMEA (note for MTS this is common to all relative devices)

	Autonomy	Independence	Segregation	Differentiation	Fault Tolerance	Fault Resistance	Fault Ride-Through
Definition	• Self-start without overarching control and provide position data to DPCS. • Report error and integrity (either to DP depending on DP capability or alternatively to external sensor validation function).	• Not susceptible to a common mode of failure with other PRS (and associated systems such as targets on remote installation).	• Good Physical separation between relative position references intended to provide redundancy in relative measurements (including their reflectors / targets).	• Different measurement principles (Example - Microwave and Laser). • Different position determination (Example – target based versus target-less).	• Ability of a PRS to continue in operation following a single fault (High probability).	• Not susceptible to failure.	• Ability to continue providing a valid position output during measurement outages and other disturbances.
Compromised by	• The need for operator intervention at start-up. • DPCS may not use external error and integrity data. • External sensor validation function not implemented or deployed. • Reflector / target installation / usage outside manufacturer specifications or best practice.	• Choice of interface protocol which may restrict use of available and relevant data. • More than one relative reference on same UPS. • Dependency on external sensors to calculate heading. • Single shared HMI for redundant systems. • Dependency on targets (e.g. specification, performance, location etc.)	• Mounting laser targets and microwave transponders on same bracket. • Lack of spatial separation of transponders / laser targets. • Co-location outside manufacturers specifications for PRSs.	• Using same principle.	• Insufficient targets to allow for targets being obscured or transponders failing. • Weather windows.	• Poor quality targets – reflective tape rather than prisms. • Poor siting of sensors. • Lack of attention to OEM maintenance recommendations. • Symmetric target spacing. • Weather conditions, Fog.	• Beam can be obscured (Example crane swinging through beam / cloud of hot steam etc.).

	Autonomy	Independence	Segregation	Differentiation	Fault Tolerance	Fault Resistance	Fault Ride-Through
Mitigated By	• Retention of configuration settings by design. • Minimise need for operator intervention. • Minimise potential for inadvertent and unwarranted operator actions. • Alarm at DP system. • External sensor validation function. • Observation of standards for target / reflector installation and usage / maintenance and audit of target installations.	• Alignment between PRS vendors and DPCS vendor on interface protocols. • Different UPSs for each relative PRS. • Ability to display HMI in multiple places (e.g. multiple multi-function HMIs). • Use of additional target-less PRS systems.	• Attention to spatial segregation. • Attention to redundancy of laser targets and microwave transponders. • Standard install-time survey and recording process of target / reflector infrastructure and following of recommended maintenance schedule.	• Using combination / mix of activity appropriate measurement principles. • Using combination of activity appropriate targeted and target-less technologies.	• Use at least three targets for laser based systems and two transponders for microwave based systems per side. • Use of manufacturer recommended targets with known performance specification (i.e. not random SOLAS tape handmade equipment).	• Prisms to be used for reflective surfaces. • Targets that return an identifiable signature. • Adherence to OEM maintenance recommendations. • Asymmetric target spacing. • Redundancy in relative PRSs provided by difference in measurement principle. • Regular wire inspection and cropping. Correct wire attachment to weight, maintenance of follower pulley and inspection of rope guide blocks.	• Using sufficient targets to allow the PRS to report a position when one target is obscured by an obstruction. • Spatial diversity between different targeted PRS systems (i.e. sensors AND targets to be considered).

<table>
<tr><th></th><th>Autonomy</th><th>Independence</th><th>Segregation</th><th>Differentiation</th><th>Fault Tolerance</th><th>Fault Resistance</th><th>Fault Ride-Through</th></tr>
<tr><td>GNSS</td><td>• Remarks</td><td colspan="6">• Consideration in critical sparing of equipment (susceptibility to damage).
• Surveying offsets and recording same for correct use of PRS output in DPCS is important.
• Validation and verification of offsets.
• Stringent MOC processes to be applied (relocation / installation of equipment) including initial target / responder installations and ongoing maintenance.
• Minimise need for operator intervention.
• Minimise potential for inadvertent and unwarranted operator actions.
• Compromising siting requirements introduces vulnerability to faults.
• Alignment on interfaces is crucial for confidence in PRS handling.
• Firmware updates by component / equipment manufactures not communicated to DPCS manufactures or vessel owners resulting in changes to performance or functionality.
• Utilise available technology to prevent acquisition of spurious targets (Example - ID laser targets).
• Awareness of dependence on off vessel components which could significantly impact position reference sensor performance (Example – Prisms, Transponders (power supplies, batteries), base stations, compromise of spatial segregation).
• Avoidance of hand-over of targets / responders between vessel and asset (e.g. permanent installation of targets / responders as for Acoustic PRS systems).
• Observation of maintenance requirements / intervals for targets on assets crucial to system performance.
• Loss of functionality due to line of sight, lack of detection of movement (yaw, movement of targets due to movement of installation) can be mitigated by redundancy and spatial segregation of laser targets and transponders. Recommended minimum number laser targets is three and microwave transponders two per side / for higher integrity operations targeted systems can be additionally supported by target-less systems.
• Redundant taut wires are not susceptible to most common mode failures subject to segregation in power supplies and other auxiliary services (not immune to water depth restrictions, limitations imposed by strong currents, potential interference from subsea activities).</td></tr>
<tr><td>Dependencies</td><td colspan="7">Note: Default position reported is 'scanner / head' position.
• Time stamps are not generally used by relative PRS or Taut Wires - Local reference synchronised to ship / DPCS time stamps could be used to improve data analytics, fault analysis and incident investigation.
• Heading Input is not generally used directly by relative PRS or Taut Wires - Heading data is used for transforming position to reference point at the DPCS and not the PRS.
• Relative heading can be provided from the PRS with spatial segregation of laser targets or microwave transponders even against moving targets. To provide limited fault ride-through capability. This is not applicable for moving targets?
• Attitude is generally not used by relative PRS or Taut Wires - Some relative PRS systems, desirous of improving accuracy and stability have incorporated use of MRUs / VRUs to improve accuracy and stability are desired.</td></tr>
</table>

LASER (NO REFLECTOR)

OVERVIEW

A target-less laser position reference system works by using laser beams to determine the position of a vessel without the need for a specific physical target or reference point. The system typically includes a laser scanner mounted on the vessel, which sends laser beams out in multiple directions to measure the distance from the vessel to the water surface or other nearby objects.

The laser scanner uses the time-of-flight principle, which measures the time it takes for the laser beams to travel from the scanner to the surface and back. The system then calculates an outline of the target structure and hence the vessel's position based on the distance readings, which are combined with other data, such as GPS or heading data, to provide a precise position estimate.

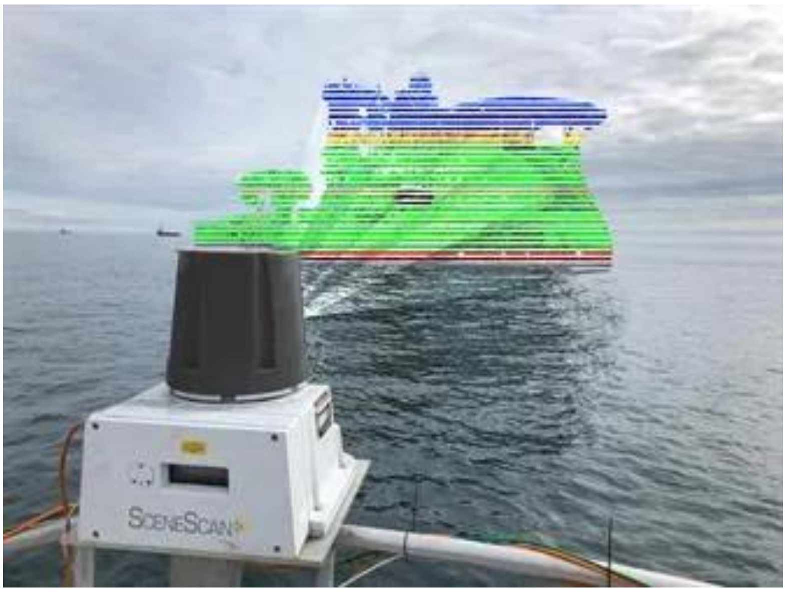


FIGURE 20 - WÄRTSILÄ SCENESCAN

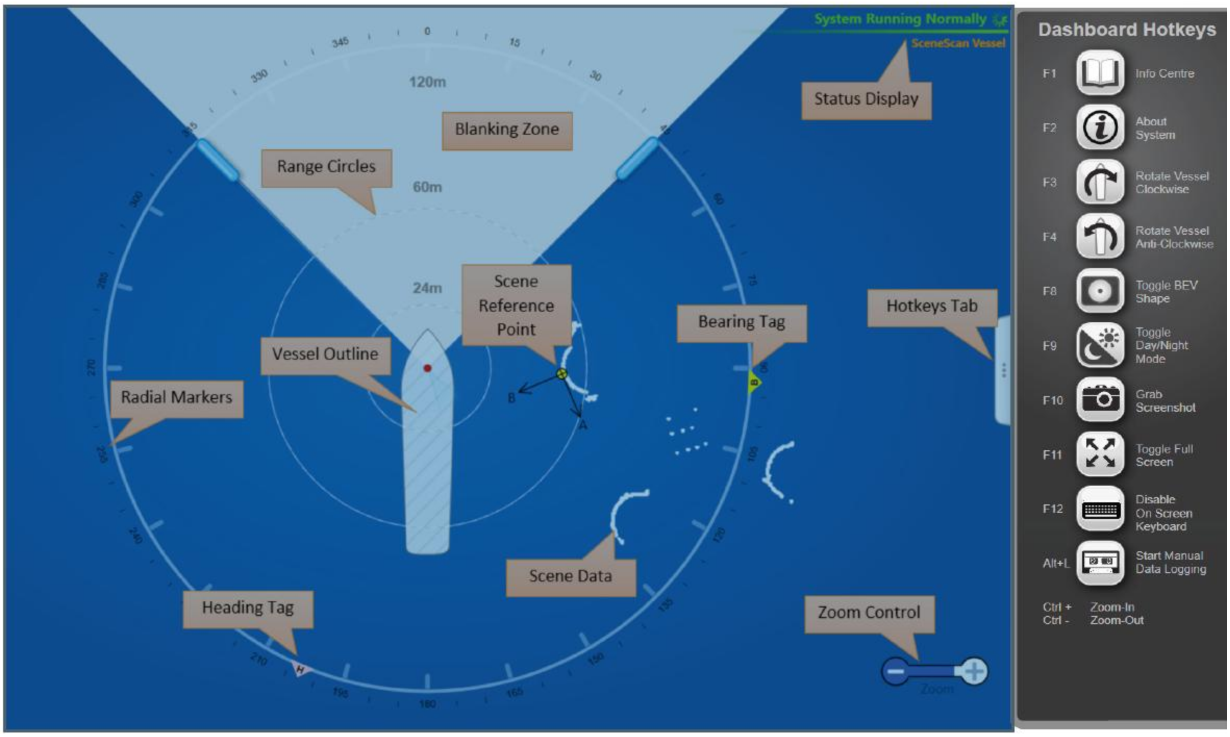
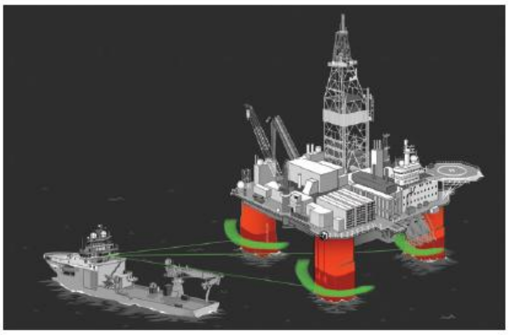
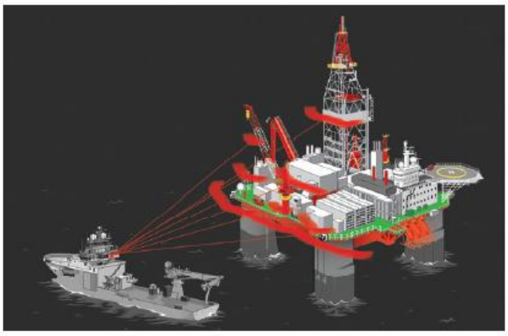


FIGURE 21 - SCENESCAN HMI



Vertical features visible from multiple sides of a rig are good when wanting to transition around the asset.



Different features closely located at slightly different elevations are poor targets to track off. Protruding features of the asset are also not advised to track off.

FIGURE 22 - SCENSCAN SET UP

Wärtsilä SceneScan The first targetless laser reference sensor brochure

User Guide

ADVANTAGE, DISADVANTAGE OPERATIONAL & FAILURE CONSIDERATIONS

Advantages	Disadvantages
High accuracy: The laser measurement technology used in the target-less system provides high accuracy, similar to traditional laser	High cost: The technology and equipment required for the target-less system may be more expensive, making it a more costly option compared to traditional navigation methods.
The target-less system does not require physical reference points or targets, making it ideal for use in offshore locations where otherwise many targets would be required. (windfarms etc.)	Maintenance requirements: The system requires regular maintenance and adding to the overall cost of ownership.
System may operate at up to 2 hz (to be checked)	Limited range: The laser beams used in the system are limited in range and may suffer in low visibility conditions.
Quick to set up as no sending of targets is required. Saving time for the actual operation.	Interference: The laser beams used in the system may be interfered with by other sources, such as other laser systems, bright low sun, fog or rain.

LESSONS LEARNT FROM DP EVENTS

None available to date

NEW DEVELOPMENTS IN LAST 5 YEARS

In 2020 IMCA released M 252 Rev 01 Guidance on position reference systems and sensors. IMCA M 252 offers the following tabulation of Laser position refence system mapped against operational considerations.

Subject	**Operational Considerations**
Target Less System	With no targets to deploy the system is ready for immediate use when entering the work area. The system relies on structures that provide a changing profile therefore reliance may not be possible given high straight sided assets. Ensure that the system has the correct size set for the vessel and correct offsets. Returns inside the envelope of the vessel are ignored by the tracking algorithm.
Keelson Clarification	The system is relatively new to the industry, and we need to get real operational case studies to evaluate the effectiveness in real world operations.

PRACTICAL ONBOARD EXERCISE

Look at your current vessels FMEA, and DP Operations manual and ASOG. Do your current operating conditions offer any restrictions to the use of target-less lasers as a position reference system?

Would a targetless system be appropriate for your vessels operations? Thinks about where is could be very useful?

MTS TECHOP (D-09 - Rev1 - Jan21) PRS AND DPCS HANDLING OF PRS offers the following tabulation of target less laser position refence system mapped against their seven pillars philosophy. Consider this with reference to your current vessel's FMEA

	Autonomy	Independence	Segregation	Differentiation	Fault Tolerance	Fault Resistance	Fault Ride-Through
Definition	• Self-start without overarching control and provide position data to DPCS. • Report error and integrity (either to DP depending on DP capability or alternatively to external sensor validation function).	• Not susceptible to a common mode of failure with other PRS (and associated systems such as targets on remote installation).	• Goof Physical separation between relative position references intended to provide redundancy in relative measurements (including their reflectors / targets).	• Different measurement principles (Example - Microwave and Laser). • • Different position determination (Example – target based versus target-less).	• Ability of a PRS to continue in operation following a single fault (High probability).	• Not susceptible to failure.	• Ability to continue providing a valid position output during measurement outages and other disturbances.
Compromised by	• The need for operator intervention at start-up. • DPCS may not use external error and integrity data. • External sensor validation function not implemented or deployed. • Reflector / target installation / usage outside manufacturer specifications or best practice.	• Choice of interface protocol which may restrict use of available and relevant data. • More than one relative reference on same UPS. • Dependency on external sensors to calculate heading. • Single shared HMI for redundant systems. • Dependency on targets (e.g. specification, performance, location etc.)	• Mounting laser targets and microwave transponders on same bracket. • Lack of spatial separation of transponders / laser targets. • Co-location outside manufacturers specifications for PRSs.	• Using same principle.	• Insufficient targets to allow for targets being obscured or transponders failing. • Weather windows.	• Poor quality targets – reflective tape rather than prisms. • Poor siting of sensors. • Lack of attention to OEM maintenance recommendations. • Symmetric target spacing. • Weather conditions, Fog.	• Beam can be obscured (Example crane swinging through beam / cloud of hot steam etc.).

	Autonomy	Independence	Segregation	Differentiation	Fault Tolerance	Fault Resistance	Fault Ride-Through
Mitigated By	• Retention of configuration settings by design. • Minimise need for operator intervention. • Minimise potential for inadvertent and unwarranted operator actions. • Alarm at DP system. • External sensor validation function. • Observation of standards for target / reflector installation and usage / maintenance and audit of target installations.	• Alignment between PRS vendors and DPCS vendor on interface protocols. • Different UPSs for each relative PRS. • Ability to display HMI in multiple places (e.g. multiple multi-function HMIs). • Use of additional target-less PRS systems.	• Attention to spatial segregation. • Attention to redundancy of laser targets and microwave transponders. • Standard install-time survey and recording process of target / reflector infrastructure and following of recommended maintenance schedule.	• Using combination / mix of activity appropriate measurement principles. • Using combination of activity appropriate targeted and target-less technologies.	• Use at least three targets for laser based systems and two transponders for microwave based systems per side. • Use of manufacturer recommended targets with known performance specification (i.e. not random SOLAS tape handmade equipment).	• Prisms to be used for reflective surfaces. • Targets that return an identifiable signature. • Adherence to OEM maintenance recommendations. • Asymmetric target spacing. • Redundancy in relative PRSs provided by difference in measurement principle. • Regular wire inspection and cropping. Correct wire attachment to weight, maintenance of follower pulley and inspection of rope guide blocks.	• Using sufficient targets to allow the PRS to report a position when one target is obscured by an obstruction. • Spatial diversity between different targeted PRS systems (i.e. sensors AND targets to be considered).

Relative Devices	• **Remarks**	• Consideration in critical sparing of equipment (susceptibility to damage). • Surveying offsets and recording same for correct use of PRS output in DPCS is important. • Validation and verification of offsets. • Stringent MOC processes to be applied (relocation / installation of equipment) including initial target / responder installations and ongoing maintenance. • Minimise need for operator intervention. • Minimise potential for inadvertent and unwarranted operator actions. • Compromising siting requirements introduces vulnerability to faults. • Alignment on interfaces is crucial for confidence in PRS handling. • Firmware updates by component / equipment manufactures not communicated to DPCS manufactures or vessel owners resulting in changes to performance or functionality. • Utilise available technology to prevent acquisition of spurious targets (Example - ID laser targets). • Awareness of dependence on off vessel components which could significantly impact position reference sensor performance (Example – Prisms, Transponders (power supplies, batteries), base stations, compromise of spatial segregation). • Avoidance of hand-over of targets / responders between vessel and asset (e.g. permanent installation of targets / responders as for Acoustic PRS systems). • Observation of maintenance requirements / intervals for targets on assets crucial to system performance. • Loss of functionality due to line of sight, lack of detection of movement (yaw, movement of targets due to movement of installation) can be mitigated by redundancy and spatial segregation of laser targets and transponders. Recommended minimum number laser targets is three and microwave transponders two per side / for higher integrity operations targeted systems can be additionally supported by target-less systems. • Redundant taut wires are not susceptible to most common mode failures subject to segregation in power supplies and other auxiliary services (not immune to water depth restrictions, limitations imposed by strong currents, potential interference from subsea activities).
Dependencies	Note: Default position reported is ‘scanner / head’ position. • Time stamps are not generally used by relative PRS or Taut Wires - Local reference synchronised to ship / DPCS time stamps could be used to improve data analytics, fault analysis and incident investigation. • Heading Input is not generally used directly by relative PRS or Taut Wires - Heading data is used for transforming position to reference point at the DPCS and not the PRS. • Relative heading can be provided from the PRS with spatial segregation of laser targets or microwave transponders even against moving targets. To provide limited fault ride-through capability. This is not applicable for moving targets? • Attitude is generally not used by relative PRS or Taut Wires - Some relative PRS systems, desirous of improving accuracy and stability have incorporated use of MRUs / VRUs to improve accuracy and stability are desired.	

MICROWAVE

OVERVIEW, ADVANTAGE, DISADVANTAGE

A microwave position reference system, such as Radascan or Radius, works by measuring the time it takes for a microwave signal to travel to and from a fixed target on a vessel or structure close by. By measuring the time delay, the system can calculate the range and bearing to the target, and use this information to determine the vessel's position relative to the target.

The microwave signals used by the system are typically in the frequency range of 9 GHz, and are transmitted to the active targets in short pulses. The targets respond with a specific frequency/code to the receiver on the vessel that captures these pulses and uses them to determine the position (range and bearing) of the target relative to the transmitter. (note that the radar signals are reflected from anything solid in exactly the same way as a normal marine radar but in this case the targets respond with a different frequency so the device is able to determine difference between a target and a reflection)

Microwave position reference systems are commonly used in operations, where a second relative measurement is helpful and if visibility is a challenge to a laser-based system. They provide a reliable and accurate position reference, allowing vessels to maintain their position within a specified area.

https://dynamic-positioning.com/proceedings/dp2003/sensors_grothusen.pdf

Advantages	Disadvantages
Accuracy: Microwave position reference systems, like Radascan, can provide highly accurate (short range) position fixes	Line-of-sight: The system requires a clear line-of-sight between the transmitter and receiver.
Reliability: The system is less affected by environmental factors, such as fog, snow, heavy rain, reduced visibility.	Cost: Microwave position reference systems, like Radascan, can be more expensive to purchase and maintain than other position reference systems.
Shallow water operation: Microwave systems like Radascan are well-suited for shallow water operations where acoustics may not be possible.	Complexity: The system requires specialized knowledge and training to install, commission, and maintain, which can increase operational costs.
	Range: The range of the system may be limited, depending on the type of targets used
	Powered targets – care with explosive atmospheres and battery life

OPERATIONAL & FAILURE CONSIDERATIONS

IMCA M 252 reminds us that

> *because some of the sensors operate in the same frequency region as conventional X band radars (9.3-9.5GHz)it is essential that manufacturer recommendations regarding separation between radar units are followed*

NEW DEVELOPMENTS IN LAST 5 YEARS

In 2020 IMCA released M 252 Rev 01 Guidance on position reference systems and sensors. IMCA M 252 offers the following tabulation of Laser position refence system mapped against operational considerations.

Subject	Operational Considerations
Equipment Selection	There are a number of different manufacturers of microwave radar equipment in the market, each solution having differing characteristics for specific mission applications; for example, operating range, accuracy or operating temperature. Depending on the manufacturer, the components that make up the microwave reference system can be passive or active in nature which can determine different operating and maintenance considerations. In addition to the vendor selection, other considerations might include: • Desired number of sensors located on the fixed asset (e.g., a fixed platform may have two loading offloading zones). • Desired arrangement of sensors located on the vessel (e.g., a pipelay vessel may require more than one sensor on the vessel to allow for specific operations). • The environment in which the vessel will be operating (e.g., this technology is not susceptible to the weather related issues that cause laser based systems to suffer).
Keelson Clarification	The microwave targets are not 'passive' as they have to respond on a specific frequency. However some are battery powered but it may be possible to power then locally.
Sensor placement (vessel)	Sensor placement varies with each application therefore it is important to consider the specific application in conjunction with the manufacturer of the sensor. For example, on a platform supply vessel (PSV), the typical mounting position for the sensor may be above the wheelhouse, with a clear view over the aft deck area or whichever operating area is required. This may be different for a tanker involved in tandem offloading. Some general considerations for sensor placement are as follows: • With an unobstructed view, both vertically and horizontally, in the expected direction of the target. • Above sea-level to prevent swamping or immersion. • On a different vertical level to (or appropriately shielded from) any radar systems operating in the X-band. • On a flat, rigid, horizontal surface able to support the sensor weight. • Allowing for easy access to the connection panel and sensor information display. • High enough to be level with the corresponding sensor placed on the fixed or receiving asset. • Located such as not to cause potential interference with VSAT systems.
Sensor placement (fixed/receiving asset)	To ensure highest performance of the system and quality of the relative position data sent to the DP system, the location, range and orientation of the fixed sensor must be optimised. Ideally fixed sensors should be mounted: • Within the recommended height difference limits. • Within the tilt limits. • Facing the sensor directly. • In a permanent location. Vertical separation between fixed and vessel sensors at close range can become critical therefore pre-site planning for positioning of the fixed sensor is essential.
	Generally the radar devices do not tilt, however this means that the targets need to be within the upper and lower limits of the interrogation antenna. Also the type of target and sensor need to be appropriate for the range.

Sensor placement (fixed/receiving asset)	Other considerations are required when selecting equipment to be mounted on the fixed/receiving asset: • Will the sensors be permanently installed or temporary for a given operation (if temporary then procedures and checklists may require development to ensure correct application)? • How the unit is to be powered (mains/battery (rechargeable or non-rechargeable)) and the various technical and maintenance considerations that result. • The local environment where the sensor will be mounted (e.g. hazardous area, within a crane lifting zone, exhaust outlet, etc). • The sensor should be sited with consideration of the line of sight between the sensor and the vessel throughout the entire DP operation. • In addition to direct line of sight considerations, also bear in mind the operation itself. For example, crane operations may pass through the area and interrupt the tracking lock.
	Multiple targets?
Multipath reflection of the signal on the sea	'Multipath' is normally worse on a calm surface. Blanking, as it often is referred to, occurs when the directed signal is cancelled out by the reflected signal, causing the remaining signal to be too weak to be registered by the sensor. Operational experience has shown that the normal heave on a vessel eliminates this effect, as the blanking effect is strongly correlated with the height difference between the vessel mounted and fixed installation sensors. In microwave radar operations, the blanking effect is normally connected to the signal transmitted from the vessel mounted sensor, as the energy 'reflected' from the fixed sensor is much weaker than the transmitted signal. The effect of blanking is a result of the height of the vessel mounted and fixed installation sensors. As a general rule, the higher above the sea level the sensors are mounted, the lower the effects. The manufacturer should be engaged to determine the best course of action on a case by case basis depending on specific application. For example, the manufacturer may suggest the use of a higher gain sensor where, after the blanking effect, the signal is still strong enough to be used.
Operation of more than one system in a specific location	Systems can be set up on specific frequency 'pairs' so that mutual interference between two systems in the same area can be avoided. By giving the mobile and the fixed sensors an identical address code, they will only lock and respectively transmit when they receive the address code given. This avoids both a mobile station locking onto someone else's fixed station and a fixed station transmitting when it does not receive the correct address code. Further manufacturer specific precautions may also be necessary to avoid interference between two fixed stations for example during

Microwave Failures

Effect	Cause	Mitigation
Equipment failure	• Failure of hardware including transmitters and receivers, PCs. • Issues with software not operation or suffering corruption. • Damage or degradation in condition of transmitters and receivers, cleanliness of equipment, integrity of batteries and cables.	• Ensure that there are a minimum of three position reference systems active within the DP system based on at least two different principles and suitable for the given operating conditions as per IMO MSC/ Circ.645 6 June 1994 / MSC/ Circ.1580 16 June 2017. • During installation, commissioning, modification it is important to conduct comprehensive tests to ensure correct setup and calibration checks are adhered to. • During maintenance visits, check cables and connectors for damage, cracking and water ingress, battery integrity, transmitter/receiver cleanliness/etc.

System unable to detect 'fixed' sensor.	• Damage or degradation in condition of transmitters and receivers, cleanliness of equipment, integrity of batteries and cables, sensor obstruction.	• During maintenance visits, check cables and connectors for damage, cracking and water ingress, battery integrity, transmitter/receiver cleanliness/etc. • Check that there are no obstructions on the vessel or asset that could block or interfere with the signal, for example, a crane boom or scaffolding.
Degraded, False or no reference signals	• Coding of transmitter/receiver incorrect. • Unauthorised modification of sensor brackets. • Multipath issues, interference from X band radar.	• Incorrect setup/commissioning of system. • Sensor bracket adjustment must be reflected in the system software setup. • Correct installation location based on manufacturer recommendation.

PRACTICAL ONBOARD EXERCISE

Look at your current vessel's FMEA, and DP Operations manual and ASOG. Do your current operating conditions offer any restrictions to the use of Lasers as a position reference system?

MTS TECHOP (D-09 - Rev1 - Jan21) PRS AND DPCS HANDLING OF PRS offers the following tabulation of microwave position refence system mapped against their seven pillars philosophy. Consider this with reference to your current vessel's FMEA.

	Autonomy	Independence	Segregation	Differentiation	Fault Tolerance	Fault Resistance	Fault Ride-Through
Definition	Self-start without overarching control and provide position data to DPCS. Report error and integrity (either to DP depending on DP capability or alternatively to external sensor validation function).	Not susceptible to a common mode of failure with other PRS (and associated systems such as targets on remote installation).	Goof Physical separation between relative position references intended to provide redundancy in relative measurements (including their reflectors / targets).	Different measurement principles (Example - Microwave and Laser). Different position determination (Example – target based versus target-less).	Ability of a PRS to continue in operation following a single fault (High probability).	Not susceptible to failure.	Ability to continue providing a valid position output during measurement outages and other disturbances.
Compromised by	The need for operator intervention at start-up. DPCS may not use external error and integrity data. External sensor validation function not implemented or deployed. Reflector / target installation / usage outside manufacturer specifications or best practice.	Choice of interface protocol which may restrict use of available and relevant data. More than one relative reference on same UPS. Dependency on external sensors to calculate heading. Single shared HMI for redundant systems. Dependency on targets (e.g. specification, performance, location etc.)	Mounting laser targets and microwave transponders on same bracket. Lack of spatial separation of transponders / laser targets. Co-location outside manufacturers specifications for PRSs.	Using same principle.	Insufficient targets to allow for targets being obscured or transponders failing. Weather windows.	Poor quality targets – reflective tape rather than prisms. Poor siting of sensors. Lack of attention to OEM maintenance recommendations. Symmetric target spacing. Weather conditions, Fog.	Beam can be obscured (Example crane swinging through beam / cloud of hot steam etc.).

Mitigated By	Retention of configuration settings by design. Minimise need for operator intervention. Minimise potential for inadvertent and unwarranted operator actions. Alarm at DP system. External sensor validation function. Observation of standards for target / reflector installation and usage / maintenance and audit of target installations.	Alignment between PRS vendors and DPCS vendor on interface protocols. Different UPSs for each relative PRS. Ability to display HMI in multiple places (e.g. multiple multi-function HMIs). Use of additional target-less PRS systems.	Attention to spatial segregation. Attention to redundancy of laser targets and microwave transponders. Standard install-time survey and recording process of target / reflector infrastructure and following of recommended maintenance schedule.	Using combination / mix of activity appropriate measurement principles. Using combination of activity appropriate targeted and target-less technologies.	Use at least three targets for laser based systems and two transponders for microwave based systems per side. Use of manufacturer recommended targets with known performance specification (i.e. not random SOLAS tape handmade equipment).	Prisms to be used for reflective surfaces. Targets that return an identifiable signature. Adherence to OEM maintenance recommendations. Asymmetric target spacing. Redundancy in relative PRSs provided by difference in measurement principle. Regular wire inspection and cropping. Correct wire attachment to weight, maintenance of follower pulley and inspection of rope guide blocks.	Using sufficient targets to allow the PRS to report a position when one target is obscured by an obstruction. Spatial diversity between different targeted PRS systems (i.e. sensors AND targets to be considered).
Relative Systems	• **Remarks**	Consideration in critical sparing of equipment (susceptibility to damage). Surveying offsets and recording same for correct use of PRS output in DPCS is important. Validation and verification of offsets. Stringent MOC processes to be applied (relocation / installation of equipment) including initial target / responder installations and ongoing maintenance. Minimise need for operator intervention. Minimise potential for inadvertent and unwarranted operator actions. Compromising siting requirements introduces vulnerability to faults. Alignment on interfaces is crucial for confidence in PRS handling. Firmware updates by component / equipment manufactures not communicated to DPCS manufactures or vessel owners resulting in changes to performance or functionality. Utilise available technology to prevent acquisition of spurious targets (Example - ID laser targets). Awareness of dependence on off vessel components which could significantly impact position reference sensor performance (Example – Prisms, Transponders (power supplies, batteries), base stations, compromise of spatial segregation). Avoidance of hand-over of targets / responders between vessel and asset (e.g. permanent installation of targets / responders as for Acoustic PRS systems). Observation of maintenance requirements / intervals for targets on assets crucial to system performance. Loss of functionality due to line of sight, lack of detection of movement (yaw, movement of targets due to movement of installation) can be mitigated by redundancy and spatial segregation of laser targets and transponders. Recommended minimum number laser targets is three and microwave transponders two per side / for higher integrity operations targeted systems can be additionally supported by target-less systems. Redundant taut wires are not susceptible to most common mode failures subject to segregation in power supplies and other auxiliary services (not immune to water depth restrictions, limitations imposed by strong currents, potential interference from subsea activities).					

Dependencies	Note: Default position reported is 'scanner / head' position. Time stamps are not generally used by relative PRS or Taut Wires - Local reference synchronised to ship / DPCS time stamps could be used to improve data analytics, fault analysis and incident investigation. Heading Input is not generally used directly by relative PRS or Taut Wires - Heading data is used for transforming position to reference point at the DPCS and not the PRS. Relative heading can be provided from the PRS with spatial segregation of laser targets or microwave transponders even against moving targets. To provide limited fault ride-through capability. This is not applicable for moving targets? Attitude is generally not used by relative PRS or Taut Wires - Some relative PRS systems, desirous of improving accuracy and stability have incorporated use of MRUs / VRUs to improve accuracy and stability are desired.

OVERVIEW, ADVANTAGE, DISADVANTAGE

Taut wires compared to other position reference systems are relatively and self-contained simple mechanical devices. Their use is restricted to water depths up to around 350m.

A taut wire system operates by lowering a clump weight by wire to the seabed using a davit or A-frame. The wire is held in constant tension to prevent vessel motion from dragging the weight or allowing the wire to go slack. As the wire leaves the vessel it is taken through a 'gimbal head' with pulley and some form of wire follower with guide blocks. Attached to the follower are inclinometers, or potentiometers, that measure the angle of the wire in the fore/aft and port/starboard axes. Using the angles of the wire and either the known water depth or the measured line out, the position of the weight with respect to the vessel can be calculated.

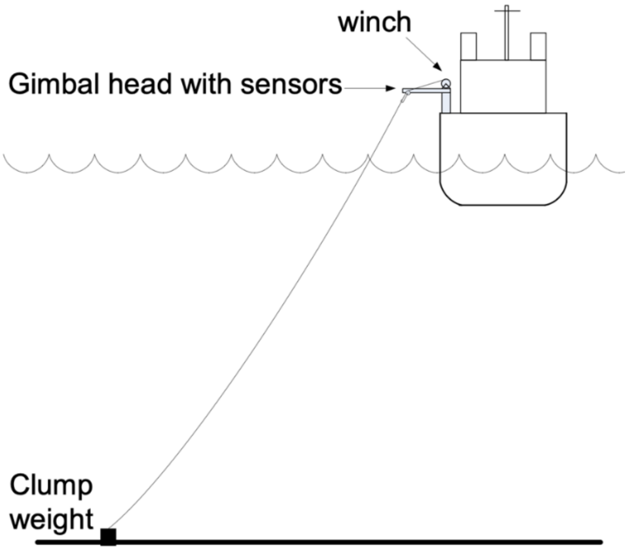


FIGURE 23 - SIMPLIFIED TAUTWIRE

In general the weight needs to be deployed over the vessel's side, although some systems have been produced that deploy through a moonpool. The means of deploying the weight must achieve two things; firstly to get the weight sufficiently outboard to give the vessel reasonable room to manoeuvre before the wire touches the vessel's side. Secondly it needs to provide the necessary distance to allow the wire spooling gear or self-spooling winch to operate correctly. This second item only applies to systems that use a winch; those that use a counterbalance do not have this restraint. Generally though, recent 'over the side' systems are either an A frame design or a davit. The A frame has the advantage of occupying the minimum deck space but do not get the weight as far over the side as a davit can. They also tend to need spooling gear and this can produce other problems. Some form of weight catching and securing also needs to be considered. Note that since the weight must be lowered in a steady and controlled fashion the energy expended in converting potential to kinetic energy must be dissipated somewhere within the taut wire mechanism.

OPERATIONAL & FAILURE CONSIDERATIONS

When using a taut wire as a position reference system offshore, the following operational considerations should be taken into account:

- Tension: The wire must be kept under sufficient tension at all times to ensure the wire is held as straight as possible to assist with accurate readings but not too much that would risk 'lifting' or 'dragging' the weight.
- Wire breakage: The wire is subject to damage from use, corrosion, and other external factors, so regular inspections should be conducted to ensure it remains in good condition. If used where the seabed is muddy

the weight can sink in and then when it needs to be retrieved the suction effect causes additional tension on the wire and there will be a tendency to snap at any weak spot.

- Depth measurement: The taut wire system requires accurate depth measurements.
- Environmental conditions: Adverse conditions, such as high currents (causing the wire to bend) and waves (causing vessel pitch and roll), can affect the accuracy of the taut wire readings.
- Sensor calibration: The sensors measuring the wire's deflection must be regularly calibrated to ensure accurate readings.
- Maintenance: Regular maintenance is required to keep the taut wire system in good working order, including tightening/greasing the wire, checking the inclinometers, and replacing any damaged components.
- Integration with DP system: The taut wire system must be integrated with the vessel's DP system for the position readings to be used effectively.
- Some Taut wire systems measure the angle of the wire relative to the A-frame (rather than the vertical) so the compensation for the vessel motion is done in the DP using data from the MRU/VRUs, ensure they are working and are an appropriate accuracy for the water depth.

NOTE MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) states that

> *18.5.5 Taut wire: Taut wire systems are known to suffer inaccuracies at water depths over 350m, especially in high current areas. Design should not consider Taut Wires as one of the three position references required by class if operations are contemplated in water depths over 350m.*

LESSONS LEARNT FROM DP EVENTS

DP Event Bulletin	ITEMS
IMCA Safety Flash 13/11 November 2011	Near-miss: Dropped taut wire clump weight
IMCA Safety Flash 14/06 December 2006	Near-miss: Divers nearly hit by weight on taut wire

PRACTICAL ONBOARD EXERCISE

Look at your current vessels FMEA, and DP Operations manual and ASOG. Do your current operating conditions offer any restrictions to the use of Lasers as a position reference system.

NEW DEVELOPMENTS IN LAST 5 YEARS

In 2020 IMCA released M 252 Rev 01 Guidance on position reference systems and sensors. IMCA M 252 offers the following tabulation of taut wire position refence system mapped against operational considerations.

Subject	Operational Considerations
Equipment Selection	There are a number of different manufacturers of taut wire position reference equipment in the market, each solution having slightly differing characteristics. In addition to the vendor selection, other considerations might include: • Water depth at operating location – the use of Taut Wire can be limited by the water depth (< 500m) and therefore more applicable to shallower water operations. Greater water depth solutions have been designed; however, they inherently suffer accuracy issues as any variation in wire tension directly causes an almost proportional variation in the estimated position of the weight. • Mission of the vessel – the Taut Wire is only suitable for activities on a small footprint (heading and position) and therefore would not always be suitable. The shallower the operation, the smaller the permissible footprint. The Taut Wire system can also suffer long term drift as the current changes the catenary. • The environment in which the vessel will be operating (e.g., heave, pitch and rolling). The inertia of the wire rope, plus any friction has to be overcome as does the inertia of the wire drum. Whenever the vessel heaves, rolls or pitches, the Taut Wire has to pay out or pay in wire, and so it has to overcome the inertia, dead bands, back lash and friction of all the mechanical moving parts. This means that the system must always have a finite response time; this therefore contributes to the degrading of accuracy of the tension control. • A system incorporating 'walking Taut Wires' has been developed. With two Taut Wires in use, the system will automatically re-set one of the Taut Wires once a specified angle within operational limits has been reached. The system can be used for pipelaying operations, although has become less important due to availability of alternative PRS.
Keelson Clarification	Due to the limitation on vessel movement, the location of the clump weight will need to be planned well. Any automatic retrieval needs to be carefully planned and monitored.
Deployment	Consideration must be given during Taut Wire deployment due to: • Ensuring no risk to vessel personnel (e.g., divers) or equipment (e.g., ROVs) in the water at the point of deployment. • Subsea Infrastructure at location – the Taut Wire requires a weight to be placed on the seabed and therefore the location of subsea equipment (e.g., templates, risers, mooring lines, umbilical's, etc.) and seabed condition require consideration.
	If the vessel is rolling/pitching when the weight is being deployed or retrieved and above the water swinging can occur. There have been many instances of the weight impacting inclinometer and pully system during retrieval, this generally cases the wire to snap, the weight to be lost to the seabed, and significant damage to the Taut wire system.

Taut Wire Failures

Effect	Cause	Mitigation
Inaccurate position reference	• Thruster wash, creep over time due to current, fouling of clump wire including the Taut Wire touching the side of own vessel or otherwise being restricted in its movement, or by a faulty gimbal sensor.	• Operational and mission awareness is the best mitigation for most of the possible causes of taut wire reference inaccuracy.

Wire break	• Taut Wires are quite highly stressed for marine wire ropes and are liable to breakage, particularly at points of weakness, such as continuous ‘spot’ wear on the main sheave, continuous wear at any guide blocks and kinks or damage caused by poor spooling or where the wire is attached to the weight.	• The potential for wire breakage is reduced by regular inspection and maintenance of the Taut Wire system and by cropping the Taut Wire on a regular basis.

ABOVE and beyond

MTS TECHOP (D-09 - Rev1 - Jan21) PRS AND DPCS HANDLING OF PRS offers the following tabulation of a taut wire position refence system mapped against their seven pillars philosophy. Consider this with reference to your current vessel's FMEA

	Autonomy	Independence	Segregation	Differentiation	Fault Tolerance	Fault Resistance	Fault Ride-Through
Definition	• Self-start without overarching control and provide position data to DPCS. 6. Report error and integrity (either to DP depending on DP capability or alternatively to external sensor validation function).	• Not susceptible to a common mode of failure with other PRS (and associated systems such as targets on remote installation).	• Goof Physical separation between relative position references intended to provide redundancy in relative measurements (including their reflectors / targets).	• Different measurement principles (Example - Microwave and Laser). • Different position determination (Example – target based versus target-less).	• Ability of a PRS to continue in operation following a single fault (High probability).	• Not susceptible to failure.	• Ability to continue providing a valid position output during measurement outages and other disturbances.
Compromised by	• The need for operator intervention at start-up. • DPCS may not use external error and integrity data. • External sensor validation function not implemented or deployed. • Reflector / target installation / usage outside manufacturer specifications or best practice.	• Choice of interface protocol which may restrict use of available and relevant data. • More than one relative reference on same UPS. • Dependency on external sensors to calculate heading. • Single shared HMI for redundant systems. • Dependency on targets (e.g. specification, performance, location etc.)	• Mounting laser targets and microwave transponders on same bracket. • Lack of spatial separation of transponders / laser targets. • Co-location outside manufacturers specifications for PRSs.	• Using same principle.	• Insufficient targets to allow for targets being obscured or transponders failing. • Weather windows.	• Poor quality targets – reflective tape rather than prisms. • Poor siting of sensors. • Lack of attention to OEM maintenance recommendations. • Symmetric target spacing. • Weather conditions, Fog.	• Beam can be obscured (Example crane swinging through beam / cloud of hot steam etc.).

Mitigated By	• Retention of configuration settings by design. • Minimise need for operator intervention. • Minimise potential for inadvertent and unwarranted operator actions. • Alarm at DP system. • External sensor validation function. • Observation of standards for target / reflector installation and usage / maintenance and audit of target installations.	• Alignment between PRS vendors and DPCS vendor on interface protocols. • Different UPSs for each relative PRS. • Ability to display HMI in multiple places (e.g. multiple multi-function HMIs). • Use of additional target-less PRS systems.	• Attention to spatial segregation. • Attention to redundancy of laser targets and microwave transponders. • Standard install-time survey and recording process of target / reflector infrastructure and following of recommended maintenance schedule.	• Using combination / mix of activity appropriate measurement principles. • Using combination of activity appropriate targeted and target-less technologies.	• Use at least three targets for laser based systems and two transponders for microwave based systems per side. • Use of manufacturer recommended targets with known performance specification (i.e. not random SOLAS tape handmade equipment).	• Prisms to be used for reflective surfaces. • Targets that return an identifiable signature. • Adherence to OEM maintenance recommendations. • Asymmetric target spacing. • Redundancy in relative PRSs provided by difference in measurement principle. • Regular wire inspection and cropping. Correct wire attachment to weight, maintenance of follower pulley and inspection of rope guide blocks.	• Using sufficient targets to allow the PRS to report a position when one target is obscured by an obstruction. • Spatial diversity between different targeted PRS systems (i.e. sensors AND targets to be considered).

Relative Systems	• **Remarks**	• Consideration in critical sparing of equipment (susceptibility to damage). • Surveying offsets and recording same for correct use of PRS output in DPCS is important. • Validation and verification of offsets. • Stringent MOC processes to be applied (relocation / installation of equipment) including initial target / responder installations and ongoing maintenance. • Minimise need for operator intervention. • Minimise potential for inadvertent and unwarranted operator actions. • Compromising siting requirements introduces vulnerability to faults. • Alignment on interfaces is crucial for confidence in PRS handling. • Firmware updates by component / equipment manufactures not communicated to DPCS manufactures or vessel owners resulting in changes to performance or functionality. • Utilise available technology to prevent acquisition of spurious targets (Example - ID laser targets). • Awareness of dependence on off vessel components which could significantly impact position reference sensor performance (Example – Prisms, Transponders (power supplies, batteries), base stations, compromise of spatial segregation). • Avoidance of hand-over of targets / responders between vessel and asset (e.g. permanent installation of targets / responders as for Acoustic PRS systems). • Observation of maintenance requirements / intervals for targets on assets crucial to system performance. • Loss of functionality due to line of sight, lack of detection of movement (yaw, movement of targets due to movement of installation) can be mitigated by redundancy and spatial segregation of laser targets and transponders. Recommended minimum number laser targets is three and microwave transponders two per side / for higher integrity operations targeted systems can be additionally supported by target-less systems. • Redundant taut wires are not susceptible to most common mode failures subject to segregation in power supplies and other auxiliary services (not immune to water depth restrictions, limitations imposed by strong currents, potential interference from subsea activities).
Dependencies	Note: Default position reported is 'scanner / head' position. • Time stamps are not generally used by relative PRS or Taut Wires - Local reference synchronised to ship / DPCS time stamps could be used to improve data analytics, fault analysis and incident investigation. • Heading Input is not generally used directly by relative PRS or Taut Wires - Heading data is used for transforming position to reference point at the DPCS and not the PRS. • Relative heading can be provided from the PRS with spatial segregation of laser targets or microwave transponders even against moving targets. To provide limited fault ride-through capability. This is not applicable for moving targets? • Attitude is generally not used by relative PRS or Taut Wires - Some relative PRS systems, desirous of improving accuracy and stability have incorporated use of MRUs / VRUs to improve accuracy and stability are desired.	

HYDROACOUSTIC

OVERVIEW

A hydroacoustic position reference system (HPRS) uses underwater sound waves to determine the position of a vessel. It works by emitting acoustic signals from a transducer (Transceiver) mounted on the vessel and receiving the signals from targets (Transponders) on the seafloor or underwater structures or vehicles. The time of flight between the emission and reception of the acoustic signals is then used to calculate the distance between the vessel and each Transponder.

The HPRS uses this information from several transponders to determine the vessel's position relative to a known reference point. The HPRS processes this information in real-time, allowing the vessel's position to be continuously updated. The update rate will depend on factors discussed below.

The following pages discuss the various ways in which acoustics are used to provide position data.

The HPRS is useful in environments where no other references other than GNSS are available. It is also commonly used in underwater operations, diving, dredging, ROV and subsea construction. The HPRS provides high accuracy and reliability, making it an important tool for navigation and positioning in underwater environments.

ADVANTAGE, DISADVANTAGE

Advantages	Disadvantages
Useable accuracy: The HPRS provides usable-precision position data	Limited range: The HPRS has a limited range, when being used in deep-water environments it must be well planned with appropriate selection of Transceiver and rated seabed transponders..
GNSS independence: The HPRS operates independently of GNSS signals, making it usable in areas where GNSS signals may be interrupted	Interference: The HPRS can be affected by environmental factors such as noise or interference from other acoustic sources, particularly thruster noise, but also air bubbles and the presence of marine life can attenuate signals significantly.
Real-time updates: The HPRS provides real-time updates, allowing the vessel's position to be continuously monitored. (see notes regarding update rates)	Complexity: The HPRS requires specialized equipment and a high level of technical expertise to operate and maintain.
Reliability: The HPRS is a reliable positioning system, especially if more than the minimum number of seabed transponders are deployed	Vulnerability to damage: The HPRS components are vulnerable to damage, requiring careful handling and maintenance.
	Expensive: The HPRS may not be a cost-effective solution, but it may be the only solution.
	In shallow water reflections off the seabed etc can cause inaccuracy unless appropriate mitigation is made.

OPERATIONAL & FAILURE CONSIDERATIONS

The distance between acoustic baselines is generally used to define an acoustic positioning system – that is the distance between the active sensing elements. Three primary types of acoustic positioning systems are usually defined in this way.

There are three types of acoustic position reference systems in common use - ultra- or super-short baseline systems (USBL or SSBL), short baseline systems (SBL) and long baseline systems (LBL). Each has advantages and disadvantages which determine when and how each is used.

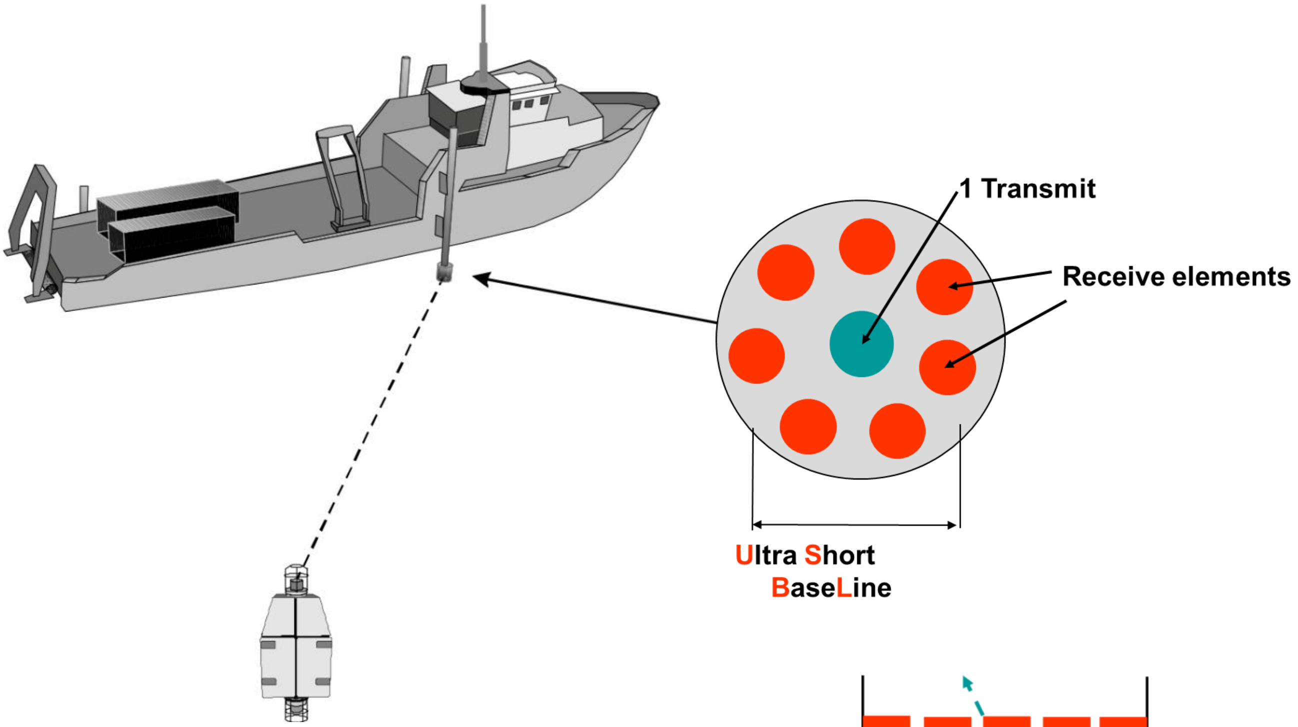
ULTRA-SHORT BASELINE (USBL) / SUPER-SHORT BASELINE (SSBL)

The ultra- or super-short baseline (SSBL) principle means that the measurement of the solid angle at the transducer is over a very short baseline (the transducer head).

An interrogating pulse is transmitted from the transducer. This pulse is received by the transponder on the seabed, which is triggered to reply. The transmitted reply is received at the transducer. The transmit/receive time delay is proportional to the angle and range that define the position of the ship relative to that of the transponder. The measured angles must be compensated for values of roll and pitch.

The vessel must deploy at least one battery-powered transponder. They can be deployed by downline from the vessel, by an ROV or simply dropped overboard.

The performance of an acoustic system is often limited by acoustic conditions in the water. Noise from vessel thrusters and other sources, aeration and turbulence will all be detrimental to efficient acoustic positioning.



There is a small time difference between the arrival of the sound at the right hand receive element and the left hand element. This allows the System to calculate the direction.

It is vital to know the angle of the receiver relative to vertical to calculate the correct position.

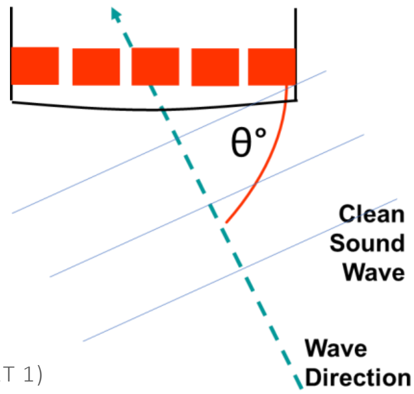


FIGURE 24 - USBL SIMPLIFIED (PART 1)

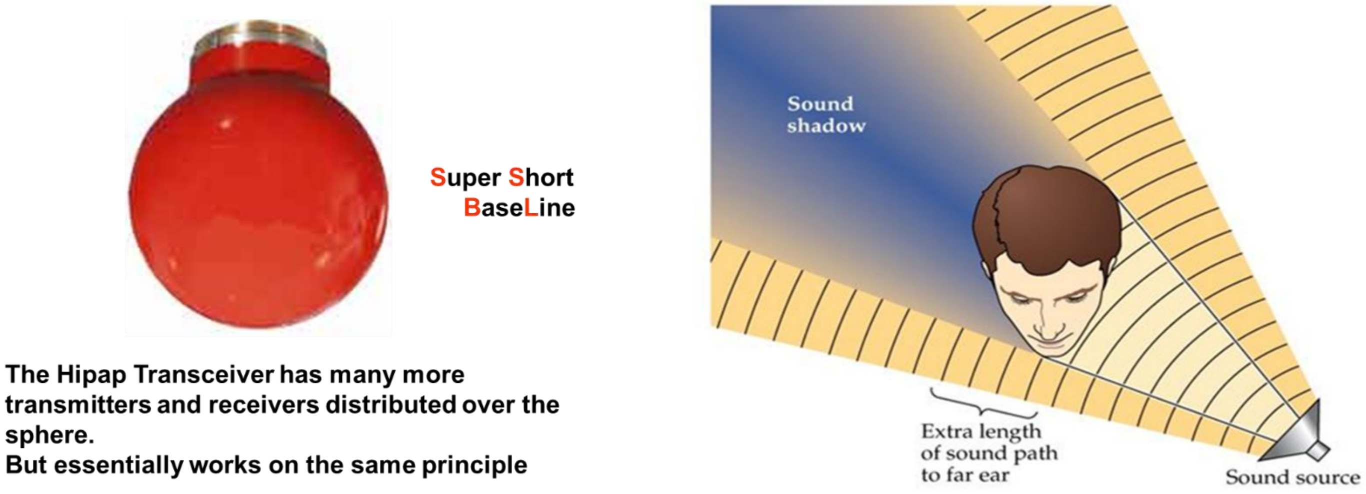


FIGURE 25 - USBL SIMPLIFIED (PART 2)

We use the same principle to judge where a sound is coming from, but we probably don’t realise it!

Advantages	Disadvantages
Low system complexity makes USBL an easy tool to use.	Detailed calibration of system required - usually not rigorously completed.
Only one Transponder required – no need to deploy a transponder array on the seafloor.	Position accuracy depends on additional sensors - ship's gyro and vertical reference unit.
Only a single transceiver at the surface – one pole/deployment machine.	Minimal redundancy – only a few commercial systems offer an over-determined solution.
Good range accuracy with time of flight systems.	Large transceiver/transducer gate valve or pole deployment machine to provide a high degree of repeatability of alignment.
	Limited by range v accuracy (but does depend on operation etc)

LONG BASELINE SYSTEM

In deep water locations, where the accuracy of the other types degrades, the long baseline (LBL) becomes more appropriate. LBL systems are in extensive use in drilling operations in deep water areas (>1,000m). The long baseline system uses an array of three or more transponders laid on the seabed in the vicinity of the worksite. Typically the array will form a pentagon (5 transponders) on the seabed, with the drillship at the centre above. One transducer upon the vessel interrogates the transponder array, but instead of measuring range and angular information, only ranges are measured, because the baseline distances have already been calibrated (distances between transponders). Position reference is obtained from range-range geometry from the transponder locations. Calibration is done by allowing each transponder to interrogate all the others in the array, in turn. If, at the same time, the vessel has a DGPS or other geographically referenced system, then the transponder array may also be geographically calibrated. Accuracy is of the order of a few metres, but the update rate can be slow in deep water because the speed of sound in sea water is about 1,500 m/sec.

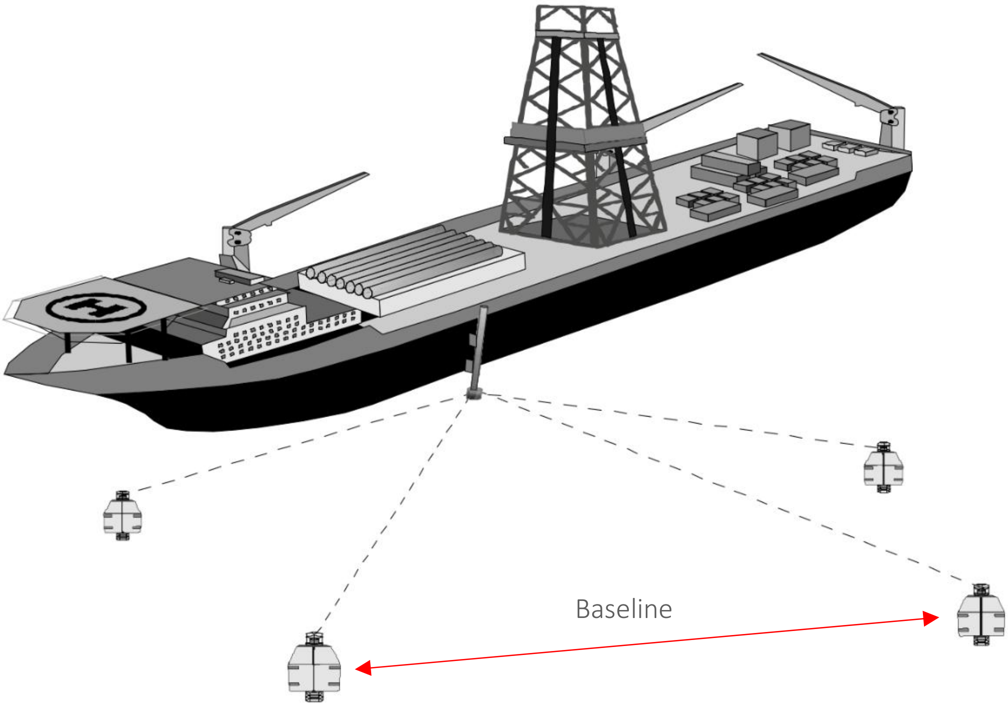


FIGURE 26 - LBL SIMPLIFIED

Advantages	Disadvantages
Very good position accuracy independent of water depth.	Complex system requiring expert operators.
Observation redundancy (assuming >3 transponders).	Large arrays of expensive equipment.
Can provide high relative accuracy positioning over large areas.	Operational time consumed for deployment/recovery.
Does not need a VRU or Gyro	Conventional systems require comprehensive calibration at each deployment.
Small transceiver – only one deployment machine/pole.	In deeper water stronger signals required and hence battery energy dissipated more rapidly

SHORT BASELINE SYSTEM

Short baseline systems derive a bearing to a beacon from multiple (≥3) surface mounted transceivers. This bearing is derived from the detection of the relative "time of arrival" as a ping passes each of the transceivers. If a time of flight interrogation technique is used (transponder or responder) a range to that beacon will also be available from the SBL system. A SBL system can work in pinger, responder or transponder mode. Any range and bearing (position) derived from a SBL system is with respect to the transceivers mounted on the vessel and as such a SBL system needs a vertical reference unit (VRU), a gyro, and possibly a surface navigation system to provide a position that is seafloor (earth) referenced.

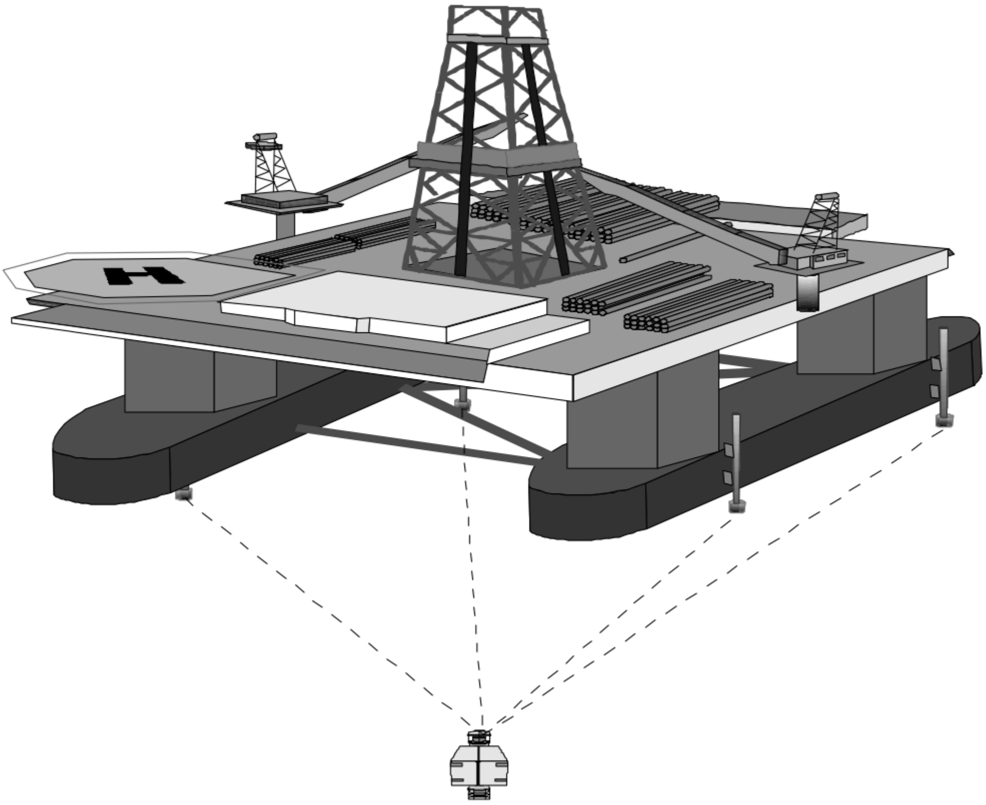


FIGURE 27 - SBL SIMPLIFIED

Advantages	Disadvantages
Low system complexity makes SBL an easy tool to use.	System needs large baselines for accuracy in deep water (>30m).
Good update rate when used with a pinger	Very good dry dock/structure calibration required.
Good range accuracy with time of flight system.	Detailed offshore calibration of system required - usually not rigorously completed.
Spatial redundancy built in.	Absolute position accuracy depends on additional sensors - ship's gyro and vertical reference unit.
Ship based system – no need to deploy transponders on the seafloor.	>3 transceiver deployment poles/machines needed.
Small transducers/gate values	

NASNET© ACOUSTICS

Nautronix has developed an alternative top the traditional acoustics, that works is a similar way to GPS but underwater.

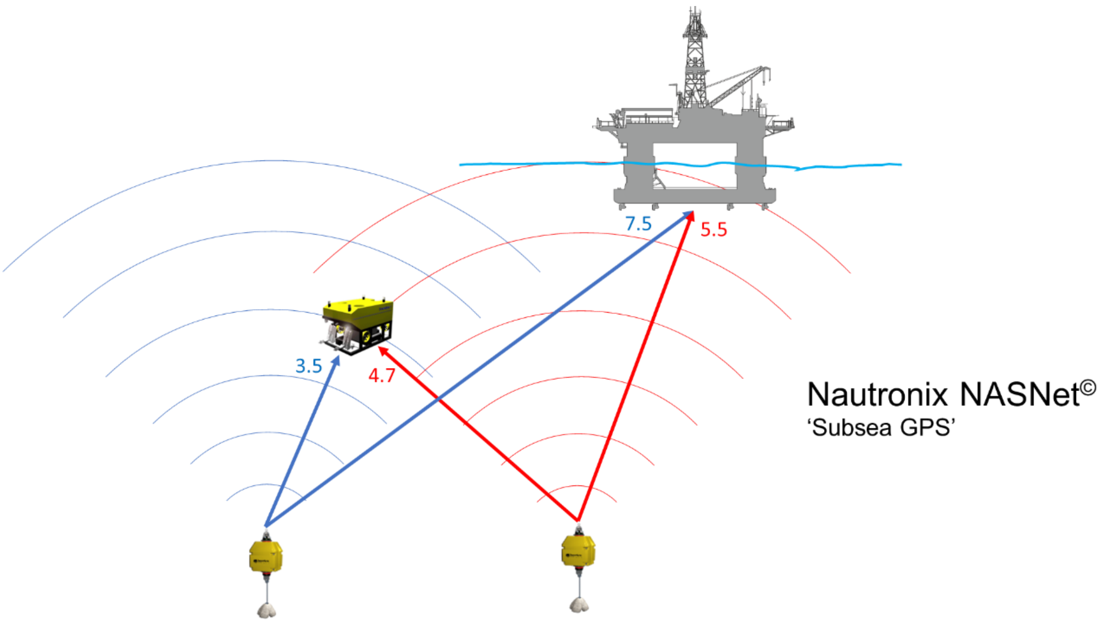


FIGURE 28 - NAUTRONIX NASNET

The illustration shows only two seabed transponders but the system needs at least four (in three dimensions). Each transponders is 'pulsing' continuously, so each 'receiver' is able to calculate its distance from each transponder and hence triangulate its own position. This allows multiple users to use the system with no interference between the users.

LESSONS LEARNT FROM DP EVENTS

DP Event Bulletin	ITEMS
Safety Flash 34/21 – December 2021	Importance of safety by design: acoustic beacon damage in splash zone
Safety Flash 16/22 – July 2022	Damage to bulwarks during overboarding of mattresses

NEW DEVELOPMENTS IN LAST 5 YEARS

In 2019 the International Association of Oil and Gas Producers released report 624-01 Common Industry Technical Specification for the Calibration and Verification of Ultra Short Baseline (USBL) Positioning Systems

In 2017 IMCA released MCA M 200, IMCA S 013 Deep water acoustic positioning intended to provide an authoritative guide for users and potential users of acoustics for underwater positioning, particularly in deep water. The document covers the basics of acoustics and signalling, the equipment required, methods of acoustic positioning and their limitations, and the operation and performance of acoustic positioning systems. The focus is on the use of acoustic positioning systems and techniques for deep water operations, though it should be recognised that many of the techniques and applications are also applicable to shallow water.

This is a useful document when trying to understand the principles of acoustics so if available it is worth a read!

In 2020 IMCA released M 252 Rev 01 Guidance on position reference systems and sensors. IMCA M 252 offers the following tabulation of acoustic position refence system mapped against operational considerations.

Subject	Operational Considerations
General	Methods of deep-water acoustic positioning vary in terms of accuracy, precision, design and frequency. How accurate or precise a system will be is dependent on commercial requirements and the operational and environmental conditions in which they will be used. In all cases, it is only possible to monitor and assess the quality and reliability of the systems if there are sufficient observations and data redundancy supported by careful system calibration and monitoring during operation. In addition to the options of LBL, SBL and USBL, some manufacturers offer a combined package of two or more of the options to provide solutions for complex offshore positioning applications. Combined solutions have the potential to allow faster updates of positioning, better mitigation against errors or interference, less equipment requiring deployment and potentially more efficient support of multiple operations. Other factors which can affect acoustic position reference systems and therefore require to be carefully considered are: Array planning (mainly LBL systems) – the planning of the layout of acoustic array to ensure consistent and reliable results in the field; Distance restrictions on range; The local seabed terrain; Geometry planning & preparation. For all of these reasons, it is important to have an acoustic management plan in place to avoid undesired interference.
Keelson Notes	Older systems based on 'tones' (frequency 'chirp') had limited number of channels and could suffer if noise in the water was close to some of those channels further restricting the remaining channels. More recent developments have added 'coding' to each frequency and increasing the number of available channels. However, with 'simops' it is important to be aware of channels that may be used by others in the area.
Deep-water Operations	Accurate heading input will enhance accuracy. Systems utilising GNSS and inertial measurement are used in preference to conventional gyros
Keelson Notes	Care needs to be taken when using GNSS into the DP and to support another PRS. Heading is more important if using SSBL as the orientation of the transceiver head is critical when using a single transponder. For most deepwater application LBL will be used. In LBL heading is required to offset the transceiver head location to the vessel centre (which is normally what the DP receives. When using INS aiding it is important to understand the failure modes and how the faults are indicated and what effect spurious fixes could have on the DP system
LBL	LBL has the highest potential accuracy of all the commercial options; the accuracy is preserved over a wider operating area, only one hydrophone is needed through the hull of the vessel, and systems have redundant data for statistical testing/quality control. LBL systems require multiple seabed/subsea transponders, the update intervals are longer compared with SBL/USBL system, and there is a need to redeploy and recalibrate at each worksite.
Keelson Notes	Due to the update intervals being longer there is a trend towards aiding with INS, to fill in the gaps between actual calculated fixes. Deep water requires stronger signals from the seabed, so battery life needs to be monitored with replacement transponders available.
SBL	SBL has good potential accuracy, requires only a subsea pinger, and has a 'one-time' calibration requirement. The accuracy is dependent on a shipboard motion and heading sensors. Unlike LBL, multiple hydrophones are required to be installed through the hull of the vessel.
Keelson Notes	Due to the additional Capital costs of the deployment machines, transceivers etc there are not so many short baseline systems now

USBL / SSBL	USBL has good potential accuracy, requires only a subsea pinger or transponder, and has a 'one-time' calibration requirement. USBL systems have the highest noise susceptibility, and accuracy is dependent on the shipboard motion sensor.
Keelson Notes	For USBL the MRU supporting the Acoustics should be of the highest accuracy as often the 'slant range' may be in the order of 2000 metres and at that range a 0.1 degree error could translate to 3.49 metres. Often USBL is used to track an ROV and the DP needs to be told that the target is mobile.
Hydrophone	The hydrophone should be installed in a relatively noise free location safe from obstructions and signal blanking, and ideally offering access for maintenance. In addition, the hydrophone needs to have its linear and rotational motion compensated for in order to remove biases due to these effects. The selection of a hydrophone location is usually based on the following criteria: • Ease of access for maintenance and possible raising and lowering; • Ability to clear the hull by a suitable amount (greater than 2m); • Level of noise and freedom from obstructions; • Relative motion of the unit with respect to the ship's centre of gravity and reference points. For multiple hydrophone installations each unit requires consideration of the above criteria, and, in addition, the relative distribution of the other hydrophones must be considered.
Keelson Notes	The Hydrophone is also known as the transceiver (as it transmits and receives the signals) The hydrophone can usually be accessed from a isolatable chest at the bottom of the deployment machine. The isolation is normally by a large gate valve. It is important that this is closed and opened on a regular basis to ensure the seal surfaces stay clear of marine growth, and it will seal when access to the Hydrophone is required.
Transducer Pole	The basic criteria for a transducer pole are: • It should withstand the rigours of the motion and forces acted on it by the water when the vessel is at sea; • It should provide a stable point, with minimal vibration, to generate and receive acoustic signals; • It should be free from local acoustic interference. Some operations may use vessels of opportunity and deploy an over-the-side pole for temporary use. Such a mounting is inherently prone to vibration, which can seriously affect the acoustic signalling at the transducer head. Having selected a suitable location point on the vessel, the physical size and length of the transducer pole should be considered. If it is too long, it could flex in the water when the vessel is underway. In general, a clearance from the hull of 1-2m is considered adequate, but it is recommended that the manufacturer is consulted to ensure that their recommendations and experience are taken into account. The diameter should be of sufficient size to provide a rigid mounting for the transducer, typically 25cm. Another aspect that should be addressed is the possibility of a round transducer pole rotating, either during installation or when operations are underway. The transducer heads of most USBL systems need to be aligned accurately and fixed so that a reliable direction can be derived for any received ranges.
Keelson Notes	Please read the manufacturers recommendation on the maximum speed allowable for a deployed pole. Any deployment system should be checked to ensure it is appropriate for the operations being undertaken
Seabed Units/ Transponders	The use of seabed units and various transponders in deep water requires that they are properly secured with appropriate fixings and that safe methods for deployment and recovery are adopted. The housings and pressure vessels required for use in deep-water are frequently large and heavy, requiring lifting equipment and special storage facilities to keep them secure whilst on-board. The deployment of systems starts with the testing and checking of units on deck prior to placing them on the seabed. For the units being taken to the seabed, there are several approaches used. The simplest is to attach a clump weight and a flotation collar to the transponder and release the unit over the side. The unit will then drop to the seabed where it will be monitored for correct operation and its co-ordinates determined by means of a box-in method. More sophisticated methods include using an ROV to place the unit directly into a frame or tripod at a pre-determined location on the seabed. This is, of course, a slower process and requires the ROV either to transport the units or for a work basket to be used to lower the units to the seabed for collection by the ROV. This method is used when the acoustic beacons need to be placed in specific holders on seabed assets. The above options apply to both USBL transponders/stations as well as LBL stations. A number of factors influence station deployment, including: Design of deep-water transponder frames; Suitability and use of acoustics as DP references; Depth rating of acoustic equipment; Power levels and battery technology.

Other observations	Nautronix, provide an alternative system called Nasnet. The principle being that an array of seabed transponders are sending regular time signals (similar to GNSS but underwater). The vessel hydrophone gathers the various signals and is then able to calculate the range to each one and hence the vessel position. This means that any vessel in that field with a Nasnet hydrophone is able to know their position. Click here for more information
	Though not perhaps directly input to the DP system but associated with it is the Lower ball Joint angle which often is transmitted using the acoustic system.
	Be aware of the type of acoustic head your vessel is equipped with, and the transponders. Vessel heads can be directional and so may limit the position of the vessel before transponders are lost from the solution. Some transponders come as omni directional, and others are directional. The specific operational requirements will mean that one may be more appropriate that the other. Be sure they are correctly depth rated. Click here for more information

IMCA M252 goes on to identify failure modes

Effect	**Cause**	**Mitigation**
Equipment failure	Failure of hardware including hydrophones, transducer poles, seabed transponders, MRU/gyro inputs, PCs. Issues with software not operation or suffering corruption. Damage or degradation in condition of equipment, cleanliness of equipment, integrity of system cables and batteries of seabed transponders (if applicable).	Ensure that there are a minimum of three position reference systems active within the DP system based on at least two different principles and suitable for the given operating conditions as per IMO MSC/ Circ.645 6 June 1994 / MSC/ Circ.1580 16 June 2017. During installation, commissioning, modification, it is important to conduct comprehensive tests to ensure correct setup and calibration checks are adhered to. During maintenance visits, check cables and connectors for damage, cracking and water ingress, battery integrity, equipment cleanliness/etc.
Keelson Note		Also ensure the remaining battery life remaining is enough for the operation, or there is a plan in place to replace exhausted units.
Degraded accuracy or no reference signals	Incorrect or lack of commissioning and calibration of equipment, signal interference, change in water temperature, thermoclines, pressure and density changes in the water, and changes in the salinity.	USBL – post accurate installation and alignment, rigorous calibration of the ships equipment and seabed units is required to ensure that the expected or specific quality of positioning reference is achieved. LBL by contrast, it is only when the network of stations is deployed to the seabed that time can be spent ensuring acceptable performance and accuracy are achieved by careful calibration of the seabed transponders (stations). Dependent on the co-ordination of the stations, the performance of an LBL array of stations is not generally related to the water depth. This is only partly true as the station co-ordinates are essentially derived from the vessel surface positioning by global navigation satellite system (GNSS). However, the mobile unit being tracked is positioned relative to the seabed stations, accuracy decreases as the vessel moves away from the centre of the LBL array.
Other observations	Other known problems can occur if fish gather in shoals around the hydrophone, or aeration of the water occurs. Sound travels well in water but	

	‘soft bodies’ and air bubbles absorb the energy	

PRACTICAL ONBOARD EXERCISE

Check your DP Operations Manual, FMEA, or manufactures manuals and make sure you know the limitations of your hydroacoustic systems.

MTS TECHOP (D-09 - Rev1 - Jan21) PRS AND DPCS HANDLING OF PRS offers the following tabulation of acoustic position refence system mapped against their seven pillars philosophy. Consider this with reference to your current vessel's FMEA

	Autonomy	Independence	Segregation	Differentiation	Fault Tolerance	Fault Resistance	Fault Ride-Through
Definition	• Start up without overarching control. • Report error and integrity to DP.	• Not susceptible to a common mode of failure with other PRS. • Not dependent on external sensors.	• Good physical separation between Acoustic PRSs	• Different types of equipment.	• Ability of a PRS to continue in operations following a single failure (high probability).	• Not susceptible to failure.	• Continue in operation during transient conditions.
Compromised by	• Requirement for operator interventions on startup.	• Common UPS supply gyro and VRU for more than one Acoustic PRS. • Synchronisation links between transceivers. • Shared HMI for redundant systems. • Choice of interface protocol which may restrict use of available and relevant data.	• Proximity of redundant transceiver poles. • Poor arrangement of transponders. • Proximity of receiver poles to thrusters. • Frequency conflicts.	• Lack of alignment on a uniform interface protocol. • Lack of transparency in internal computations. • Increased complexity in handling of PRS by DPCS.	• Single string designs. • Industrial mission operations (example noise shadowing etc.)	• Poor installation. • Inappropriate sensor for mission being undertaken. • Poor maintenance.	• Lack of data (example – Acoustic noise, intermitted data from transponder).
Mitigated By	• Retention of configuration settings by design. • Minimise need for operator intervention. • Minimise potential for inadvertent and unwarranted operator actions. • Alarm at DP system.	• Dedicated attitude and heading sensors. • Estimate heading acoustically from a calibrated array. • Dual independent systems in lieu of dual redundant systems. • HMI designed t to preserve independence.	• Following OEM installation recommendations. • Frequency management and SIMOPS.	• Systems engineering approach. • Alignment between PRS vendors and DPCS vendor on interface protocols. • Robust and transparent objective driven verification and validation processes.	• LBL aided inertial fall back to LBL. • LBL fall back to USBL. • Dual acoustic transceivers and poles. • OEM recommended number of seabed transponders.	• Following OEM installation recommendations. • Using appropriate sensor type. • Following OEM recommendations for servicing subsea equipment, gate valve and deployment machine.	• Resilient to short term outages of acoustic PRS. • Ability to use partial data internally within the PRS to output useable information. • Inertial aiding.

ACOUSTICS	• **Remarks**	• HMI interfaces to be designed to minimise cognitive burden on DPO. • Transparency of solution type being output to DPCS (not used by DPCS). • Surveying offsets and recording same. • Validation and verification of offsets. • Stringent MOC processes to be applied (relocation / installation of equipment). • Be aware of the potential pitfalls of diversity leading to compromising overall system performance. • Evaluate the need for introducing diversity when not significantly enhancing integrity of PRS solution. • Diversity achieved by choice of degradation of solution is not recommended (Example deliberately down grading LBL to USBL). • Minimise need for operator intervention. • Minimise potential for inadvertent and unwarranted operator actions. • Compromising siting requirements introduces vulnerability to faults (e.g. siting poles near thrusters can lead to noise, aeration and vibration problems). • Reported incidents caused by resonance due to transceiver pole design. • Alignment on interfaces is crucial for confidence in PRS handling, and comparison of performance.
Acoustic Aided Inertial	• The primary objective of Acoustic aided inertial is to deal with short term outages and effectively increase the data rate to balance weighting GNSS and Acoustic PRSs. • PRS redundancy, and Diversity in principle of PRSs negates the need for inertial to provide ride through capability for extended outages. • Has the ability to provide independent velocity, heave, roll, pitch and heading information. • Can be used to enhance resilience for short term outages of transponder signals. • Loss of inertial should not result in loss of Acoustic PRS. • Integration with INS may be achieved by a choice of loosely coupled, tightly coupled and deeply coupled methods. The relative merits must be understood and be appropriate for the industrial mission being undertaken. Loose coupling requires a position to be estimated by the PRS to. provide aiding, whereas tight and deep coupling uses acoustic measurements directly. Tight coupling therefore continues in aided INS mode even after a loosely coupled Acoustic/INS begins to operate in free inertial mode. • Firmware updates by component / equipment manufactures not communicated to PRS manufactures resulting in changes to performance or functionality.	
Dependencies	• Heading input - Heading data is used for transforming position to reference point. a. Estimate heading acoustically can be provided from a calibrated array. • Attitude - VRU is necessary for applying attitude information to measurements. • Time Stamps are not generally used - Local reference synchronised time stamps could be used to improve data analytics, fault analysis and incident investigation. • GNSS input is not needed for Acoustic PRSs to work. b. Used as reference when doing transducer alignment. c. GNSS is needed if an LBL array is being calibrated in geographical coordinates. • Default position reported is computed position with lever arm compensation applied.	

OVERVIEW, ADVANTAGE, DISADVANTAGE

GNSS positioning becomes unreliable or impossible when satellites are blocked by physical obstructions. In the maritime domain, this can be caused by massive offshore rigs. Other kinds of interference, intended or unintended, can also compromise GNSS positioning. GNSS/INS systems provide continuous (short term) 3D positioning, velocity, and attitude determination, even when GNSS signals are compromised for short periods of time.

It does so by integrating DGNSS data with inertial measurement unit (IMU). An IMU typically consist of

- gyroscopes: providing a measure angular rate
- accelerometers: providing a measure specific force/acceleration
- magnetometers (optional): measurement of the magnetic field surrounding the system to determine orientation information results

Software integrates data from the GSSS system and the IMU and when combined, GNSS and IMU augment and enhance each other. The absolute position and velocity accuracy of the GNSS can be used to compensate for errors in IMU measurements. The stable relative position of the INS can then be used to fill in the gap when the GNSS solution is degraded or unavailable.

Advantages

1. Increased accuracy: GNSS provides precise position data while INS provides precise orientation data. Combining these two systems results in a highly accurate navigation solution.

2. Robustness: INS can provide continuous navigation information even when GNSS signals are lost, making the overall system more robust.

3. Improved operational efficiency: GNSS/INS systems can reduce downtime and improve the efficiency of DP vessel operations.

4. Increased reliability: The use of multiple navigation sources provides redundancy, reducing the risk of total system failure.

Disadvantages

1. Cost: GNSS / INS navigation systems are expensive and require a significant investment from the vessel owner.

2. Maintenance: The systems need regular maintenance and calibration to ensure their accuracy and reliability, which can be time-consuming and expensive.

3. Complexity: The GNSS / INS systems are complex and require trained personnel to operate and maintain them

OPERATIONAL & FAILURE CONSIDERATIONS

NOTE MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21)

18.4.7 Inertial Aided Navigation (IAN) can create differentiation and prevent the potential for vulnerabilities due to skewing.

INS WITH ACOUSTICS

INS units have also been integrated into acoustic systems largely to fill in the 'gaps' due to the time it takes for several measurements to be made in deep water.

In deep water and LBL mode, a fix may be delivered every 5 or six seconds and hence the DP will 'rely' more on the GNSS arriving at 1 hz. Also, the standard deviation of the acoustic fix will be worse than that of the GNSS. INS can improve this situation considerably.

See Paper from MTS - 10 Years of Experience from Acoustic Aided Inertial

NEW DEVELOPMENTS IN LAST 5 YEARS

In 2021 IMCA released S 022 An introduction to inertial navigation systems. We recommend you access this document via IMCA.

IMCA S 022 goes into considerable detail about the design and operation of INS for DP vessels and lists five disadvantages that a DPO should be aware of.

7.1 Sensor Reliability

> *Some of the technologies used in INS are now also commonly found in everyday commercial applications. This vastly increased volume of production and mass market use has led to the introduction of lower grade units but has also made it necessary for professional-level INS equipment to differentiate itself through performance and reliability. In the aviation industry the mean time between failure (MTBF) of a ring laser gyro (RLG) is expected to be 5000-10000 hours. It is the related electronics that are expected to fail first.*

7.2 System Initialisation

> *All INS require a period of time to initialise and achieve optimum positioning accuracy. This period could also include time taken for the IMU to undertake a series of calibration movements. This procedure could require up to one hour of ROV time before starting a survey.*

7.3 System Complexity

> *INS is still a relatively specialist solution, and the number of specialist operators of such equipment may be limited. In some cases, specialist personnel from the manufacturer may need to be present for the initial mobilisation. The system manufacturer may need to provide appropriate sensor weighting to tune the filter to the specific installation.*

7.4 Real Time versus Post-Processing

> *Many survey operations require that the INS delivers positioning in real time, with little or no need for a post-processed solution. However it is recognised that the filtering and modelling can often be improved by some form of post-processing of the data. This requires that the appropriate INS and sensor data are recorded and that there is post-processing functionality. Not all INS solutions offer such a capability; users should consider beforehand what sort of INS is selected for a survey operation, in order to ensure that all the necessary various outputs and options are available.*

PRACTICAL ONBOARD EXERCISE

Check your DP Operations Manual, FMEA, or manufactures manuals and make sure you know the limitations of your INS systems.

GANGWAY SENSORS

OVERVIEW, ADVANTAGE, DISADVANTAGE

Previously transferring personnel to offshore facilities required a helicopter some of the times. This was obviously an expensive approach, and in bad visibility, impractical. An alternative was basket and ladder which was risky in heavy sea conditions. Gangway integration ensures a rapid mobilization during arrival procedure. Effective operations during wind turbine service operation reduce time and cost.

Gangway sensors are an opportunity to provide additional position information: The gangway has sensors that provide full knowledge of the tip position relative to the vessel. When connected to a fixed, known position, e.g., the wind turbine landing point, it is straightforward to calculate the vessel position.

Note: not all gangways provide measurements, some just compensate for the movements of the mother vessel.

FIGURE 29 - WT GANGWAY DP CONFERENCE OCTOBER 09 - 10, 2018

OPERATIONAL & FAILURE CONSIDERATIONS

We recommend you read IMCA M 254 Guidelines for Walk to Work Operations December 2021 and DNV-GL's Gangway Access to Offshore Facilities Walk-to-Work (W2W) Industry Guidance.

NEW DEVELOPMENTS IN LAST 5 YEARS LESSONS LEARNT FROM DP EVENTS

WORLD's FIRST AUTONOMOUS GANGWAY TYPE 1 WITH ARTIFICIAL INTELLIGENCE

FIGURE 30 - TYPICAL DP STATION WITH VIEW OF THE GANGWAY

- DNVGL ST-0358 type 1 approval.
- Autonomous control bumper level 3.
- Slip-off detection/function
- Operator position placed on vessel bridge
- Vessel DP system interaction.
- Vessel IAS integration

PRACTICAL ONBOARD EXERCISE

Check your DP Operations Manual, FMEA, or manufactures manuals and make sure you know the limitations of your gangway sensors systems.

ABOVE AND BEYOND

MTS DP OPERATIONS GUIDANCE PART 2 APPENDIX 1 - DP MODUS APRIL 2021 offers the following tabulation of the use of gangway sensors. Consider this with reference to your vessel's FMEA

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OVERVIEW, ADVANTAGE, DISADVANTAGE, INC. HOW WIND PROFILES CAN BE AFFECTED BY ASSET OPERATIONAL & FAILURE CONSIDERATIONS

A DP vessel is subjected to environmental forces such as wind, waves, and current. In order to maintain a certain position, these forces have to be counteracted by the vessel's propulsors.

IMO MSC/Circular 1580 states that *Vessel sensors should at least measure vessel heading, vessel motions* ***and wind speed and direction.***

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) offers guidance on the location, number, and selection of wind sensors

> *18.3.3 Careful consideration needs to be given to the location of the wind sensors. Masking by structures and the effects of downdraft from helicopter operations can cause erroneous readings. Design should consider effects of masking by structures and mitigation provided by installation of additional wind sensors.*
>
> *18.4.3 Diversity: Where systems using the same principle are involved, e****.g. 3 wind sensors, consideration should be given to having a diversity of manufacturers to avoid potential common mode failures to all three****. For example, ultrasonic wind sensors can all fail in heavy rain or lightning, it is therefore prudent to have one wind sensor from a different manufacturer and working on different principles.*
>
> *18.4.4 Similarly, it is prudent to have one of the three gyro compasses from a different manufacturer to minimize potential for common mode failures.*
>
> *18.4.5 This applies equally to sensors such as gyro compasses, VRUs and wind sensors.*

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) states that.

> *18.5.2 Wind sensors: Wind sensors are known to suffer common mode failures, such as icing in higher latitudes, lightning, heavy rain and birds. All types of wind sensors are vulnerable, including ultrasonic types.*

IMCA M103states that several vessel types could be adversely affected by wind speed and so should take this into account when using wind sensors.

Crane Vessels

A4-2.3 During load transfer the vessel will experience rapid changes in the DP control system environmental models caused by changes in draught, inertia and the wind profile of the combined vessel and lift. Alternative wind profiles and hydrodynamic models based on actual lift geometry and vessel draught should be incorporated within the control system;

Vessel wind profile may change significantly when changing the crane jib position whether or not there is a suspended load therefore it is recommended that there is a dynamic wind profile model in the DP system based on crane position;

A4-2.4 At least three independent wind sensors should be provided, positioned to allow for local disruption of wind flow caused by crane and lift position, information should be corrected to a common height at the DP control station.

Float over

Float-over operations are sensitive to wind speed and sea state.

A5-2.2 Position keeping capability plots should be developed for intact and worst case failure conditions, and should consider the windage of the load and conditions where float-over is in progress. Where possible a specific plot for the planned float-over operation should be available.

A5-2.4 At least three independent wind sensors should be provided, positioned to allow for local disruption of wind flow caused by the load, information should be corrected to a common height at the DP control station.

Drilling Vessels

A7-1.1Drilling vessels frequently operate in locations subjected to strong sea currents and large wave and wind forces.

A7-2.4 Wind sensors should be positioned to allow for local disruption of wind flow caused by the vessel design, information should be corrected to a common height at the DP control station.

Shuttle Tankers

A9-2.4 Wind sensors should be positioned to allow for local disruption of wind flow caused by the vessel's shape and structure and should be corrected to a common height at the DP control station.

A9-3.2 A weathervaning mode of positioning may be used by shuttle tankers loading from rotating surface production and storage facilities (turret moored) however specialist DP control modes will be required due to the movement of the reference loading point. Differences in draught and wind profile between the shuttle tanker and the facility may necessitate each adopting different weathervane headings as they may react differently to changes in wind and current;

Jack-up Vessels

A12-2.4 At least three independent wind sensors should be provided, these should be installed in different locations to allow for local disruption of wind flow caused by leg position. Where wind sensors are mounted at different heights then information at the DP control station should be corrected to a common height.

IMCA M 252 states that Anemometers should be

3.7.4 Installed to give minimum interference from vessel structures, all major classification societies now require three units to avoid shadowing. Anemometers are traditionally of the mechanical type with moving parts but more frequently now are of the ultrasonic type, without moving parts. For avoidance of common failures many vessels have units of both types.

LESSONS LEARNT FROM DP EVENTS

IMCA Safety Flash 12/06 October 2006

Wire break in wind sensor caused DP drive-off

A vessel suffered a DP drive-off during valve monitoring operations in open water. The wind was light – 5-10 knots – and there was good visibility. The vessel was on DP, with 2 x DGPS, 2 x taut wires and two wind sensors selected in the system. An ROV was in the water and the diving bell was on the surface with diving operations completed.

The DP operators noticed an increase in the thruster pitch followed by an 'off position' warning, whereupon both DGPS were deselected. The operators then noticed that one wind sensor was reading 60 knots – clearly an error – while the wind speed registered on the DP console was 35 knots as an average of the two sensor speeds.

The errant wind sensor was deselected immediately and the vessel position then stabilised at 17m from the original set-point.

Note: Some DP systems have software to reject extreme values and/or values that do not fluctuate.

NEW DEVELOPMENTS IN LAST 5 YEARS

Ultrasonic anemometers are designed to provide wind measurements and flexible output options.

- High quality measurements up to 60m/s (216 km/h) for normal use
- Models available up to 75m/s (270 km/h) for extreme conditions
- Unheated and heated models to match conditions and available power
- Maintenance free, ensuring low cost of ownership
- A range of output protocols ensures easy integration
- Comprehensive support includes software and technical advice.

FIGURE 31 - TYPICAL ANNEMOMETER

OVERVIEW, ADVANTAGE, DISADVANTAGE

IMO MSC/Circular 1580 states that

3.4.4 Vessel sensors

.1 Vessel sensors should at least measure vessel heading, vessel motions and wind speed and direction.

.2 When an equipment class 2 or 3 DP control system is fully dependent on correct signals from vessel sensors, these signals should be based on three systems serving the same purpose ***(i.e. this will result in at least three heading reference sensors being installed).***

CONVENTIONAL GYRO COMPASSES

The most common heading reference system used in DP operations.

Advantages	Disadvantages
It always shows true north.	It requires power, so when electoral power fails the gyro also fails.
The gyro may have a number of repeaters.	Traditional types generally need to be serviced periodically.
Gyro input can be fed to RADAR/ARPA/AUTO PILOT/ Echo Sounder.	When gyro compass stops for any reason, it will take some time to settle when it is powered up. It depends on where the axle was when gyro was re-started.
Does not use earth's magnetic field for reference.	
It will not be deflected by any external force such as magnet, iron etc.	

FIBRE OPTIC GYROCOMPASSES

A fibre-optic gyroscope senses changes in orientation using the Sagnac effect, thus performing the function of a mechanical gyroscope. However its principle of operation is instead based on the interference of light which has passed through a coil of optical fibre, which can be as long as 5 kilometres (3 mi).

Advantages	Disadvantages
A fibre optic gyro provides extremely precise rotational rate information, in part because of its lack of cross-axis sensitivity to vibration, acceleration, and shock. Unlike the classic spinning-mass gyroscope or resonant/mechanical gyroscopes, the FOG has no moving parts and doesn't rely on inertial resistance to movement. Hence, the FOG is an excellent alternative to a mechanical gyroscope.	Like all other gyroscope technologies and depending on detailed fibre optic gyro design, fibre optic gyros may require initial calibration (determining which indication corresponds to zero angular velocity).
	Some fibre optic gyro designs are sensitive to vibrations. However, when coupled with multiple-axis fibre optic gyro and accelerometers and hybridized with Global Navigational Satellite System (GNSS) data, the impact is mitigated, making fibre optic gyro systems suitable for high shock environments

OPERATIONAL & FAILURE CONSIDERATIONS

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21)

> *18.5.1 **Gyros:** Given the impact on heading/ position keeping it is recommended that vessels with an equivalent DP Class 2 notation are provided with three gyro compasses, irrespective of the requirements of the applicable Classification Society DP rules. It should be noted that some classification societies, including ABS and DNV already require three gyro compasses for a DP class 2 notation.*
>
> *Gyro compasses are normally fitted with a correction facility which inputs the vessel's latitude and speed. The effects of incorrect latitude or, more importantly, speed could result in a significant error in output heading. It is therefore important to ensure that latitude and speed corrections are applied. Some systems use automatic input from GPS for these corrections. This is not recommended since there are a number of system errors that can result in undesired heading changes. It is therefore recommended to use manual input of latitude and speed when in DP.*
>
> *The impact of high latitudes on gyro performance should be considered if relevant.*

IMCA M 252 states that

> *3.7.1 Heading reference systems are often used by other vessel navigation systems but it is essential that Independence for use by the DP system is well tried and tested. The most common heeding reference sensor Is a mechanical gyroscope unit with moving part. However, fibreoptic heading sensors without moving parts are becoming more popular. A fibre optic heading sensor is considered more reliable, more accurate and requires less maintenance*.

LESSONS LEARNT FROM DP EVENTS

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Bulletin 03/20 September 2020	Loss of gyro input causes loss of position
IMCA DP Station Keeping Event Bulletin 01/18 February 2018	An unassociated failure of one part of a gyro system affected the DP system – DP undesired event
IMCA DP Safety Flash 01/14 December 2014	Loss of three gyros on a DP-3 drill ship
IMCA Safety Flash 09/08 May 2008	Loss of DP position caused by incorrect gyro heading
DP Event Bulletin 01/22 – April 2022	Case Study – Force off Position
DP Event Bulletin 04/21 – December 2021	Configuration – PRS's Hidden Common Failure

NEW DEVELOPMENTS IN LAST 5 YEARS

See INS

MRU / VRU

Motion Reference sensors (MRU's) are used to measure data regarding the vessel's pitch, roll and heave. In terms of direct input and display by the DP system it is for information only. However, it can also be used by the DP to improve the accuracy of a GNSS and other reference systems fixes. For a GNSS as the vessel rolls the antenna will move in the x/y plane and the DP may treat this as a vessel movement. But if we know the height of the antenna and the angle of roll (and the heading) the DP can calculate any offset due to the roll at that moment. Timing is important in this process so the latency of the position of the antenna, the accuracy and instant of the roll measurement etc. are critical.

Some taut wire systems measure the angle of the wire relative to the boom (which is moving with the vessel roll and pitch) so the DP must compensate the wire angle with the instantaneous pitch/roll to give true angles relative to vertical.

Other references like acoustics (specifically in USBL or SSBL) require the most accurate measurement of the pitch and roll of the deployment pole. Generally, this data is directly into the acoustic system and the compensation is done in the acoustic system. Some acoustic systems take in multiple MRU measurements (which can help fault detection).

Note for LBL the angle of the acoustic head is not critical as the position of the vessel is now based on ranges from each transponder, and the triangulation from the locations of the transponders.

See below the statement '.. where the DP system is fully dependent on …' it is unusual for the DP to be totally reliant on pitch/roll/heave (unlike heading) however generally any recent DP 2 / 3 system will have three MRUs.

Also be aware of the differing MRU measurement accuracies available and which reference systems benefit from and require higher accuracies.

IMO MSC/Circular 1580 states that

> *3.4.4 Vessel sensors*
>
> *.1 Vessel sensors should at least measure vessel heading,* ***vessel motions*** *and wind speed and direction.*
>
> *.2 When an equipment class 2 or 3 DP control system is fully dependent on correct signals from vessel sensors, these signals should be based on three systems serving the same purpose (i.e. this will result in at least three heading reference sensors being installed).*
>
> *.3 Sensors for the same purpose which are connected to redundant systems should be arranged independently so that failure of one will not affect the others.*
>
> *.4 For equipment class 3, one of each type of sensor should be connected directly to the backup DP control system, and should be separated by an A-60 class division from the other sensors. If the data from these sensors is passed to the main DP control system for their use, this system should be arranged so that a failure in the main DP control system cannot affect the integrity of the signals to the backup DP control system.*

OVERVIEW, ADVANTAGE, DISADVANTAGE

Advantages	Disadvantages
Pitch and roll compensation can improve GNSS fixes if the antennas are moving due to roll and pitch.	For acoustics the MRUs tend to be high end, best accuracy and expensive.
If the 'lever arm' is small <40m then a relatively cheap and robust MRU may be OK	Often these require to be calibrated regularly (2-3 years)
There are some solid state units available at the low accuracy end of the market	They can be subject to 'end user undertaking' conditions (i.e. they have components that are restricted to certain countries as they could have dual use)
	They are generally sensitive to impacts so require careful handling
The fibre optic units have **no moving parts** BUT are very expensive	The fibre optic units have no moving parts BUT **are very expensive**

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21)

> *18.4 SUITABLE MOTION, HEADING AND ENVIRONMENTAL SENSORS*
>
> *18.4.1 Some PRS systems are dependent on correction of their measurements for roll and pitch noise. Sensors providing such measurements should not become a common point of failure. Examples of PRS systems that may share correction data are DGNSS, laser system, taut wire and acoustics. Three MRUs/VRUs with suitable error handing can aid in mitigating errors but PRS requiring correction should be able to use different MRUs in a manner that provides diversity of correction source and does not create a single point failure.*
>
> *Attention is drawn to IMO MSC/Circ 645 & 1580 where three MRU/VRUs are stipulated when vessel positioning is fully dependent on correct MRU/VRU signals.*

OPERATIONAL & FAILURE CONSIDERATIONS

IMCA M 252 states that

> *Typically Installed at the centre of gravity of the vessel MRUs determine pitch, roll and heave for the purpose of feeding motion compensation data to the DP position reference sensors. Generally, the MRU sensors are to be calibrated regularly for maintaining accurate operation. A fibre optic heading sensor is generally capable of also providing pitch, roll and heave signals. Therefore, fibre optic heading sensors can fulfil two functions, providing heading and MRU information without the need for dedicated MRU sensors.*

Note often the location is a 'goal' rather than a possibility. In fact, for acoustics (USBL/SSBL) the manufacturers prefer the MRU to be co-located with the deployment pole. Ignoring flex in the vessel structure the pitch and roll are the same wherever you measure. Consider an MRU on the bow of a vessel in extreme waves. The vessel will pitch violently and perhaps the bow may heave 8 metres, but the centre of the vessel may only be heaving 2 metres. The challenge for the MRU is to decouple the heave motion and the angular rotation.

We could calculate the heave on a helideck (on the bow) based on a measurement of heave and pitch at the centre of the vessel, but in fact it is better to be measuring the helideck motion at the helideck!

The MRUs generally have two possible interfaces to the DP.

The first is a serial data string using a typical NMEA protocol, where all the values are contained in the message.

The second is several analogue inputs to the control system (one each for pitch, roll and heave). So typically roll might be +/-10V = +/- 20 degrees.

Think about how failures may become apparent to the DP systems in both types of interface.

LESSONS LEARNT FROM DP EVENTS MRU

DP Event Bulletin	ITEMS
IMCA Safety Flash 03/11 April 2011	Crane motion reference unit (MRU) malfunctions after overheating
IMCA Safety Flash 08/10 December 2010	Failure to calibrate MRU led to near miss

CURRENT SENSOR

There has been much confusion about and misunderstanding of the current estimate presented on the DP screen. The theoretical background of the DP current is based on the mathematical model of a vessel. A problem may arise because all model errors will be mapped into the DP current, i.e. wind sensor errors, thruster set-point/ feedback errors, propeller inflow, thruster hull interaction, as well as the errors in the wind model characteristics and wave forces.

OVERVIEW, ADVANTAGE, DISADVANTAGE

it is not possible to obtain representative values for the current from any vessel-mounted sensor. Instead, a current value is deduced or estimated. In effect, the current value shown on-screen is an estimated current that would produce the forces that remain when all known (estimated) forces (wind via the wind model and any tensions etc) are accounted for. The DPO must be aware that this 'current' value is only a deduced value and not a real current measurement, and thus is subject to error.

Errors within the DP system such as erroneous thruster pitch feedback, or erroneous wind sensor data, perhaps from a jammed wind-vane unit. will be incorporated into the displayed current value.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21)

> *17.18 CALCULATED CURRENT*
>
> *17.18.1 Some DP control systems provide a figure for estimated sea current. The current is estimated by subtracting the overall force on the vessel (learnt) from forces derived from wind measurements applied to a wind force model of the vessel. The remaining force is assumed to be sea current and a speed and direction is estimated. This estimate is prone to inaccuracies as it also includes wave drift forces and thruster interactions to hull and other thrusters etc. It is also affected by thruster inaccuracies. Clear guidance should be provided highlighting that calculated current may not be representative of actual sea current.* ***Operational decisions should not be based on calculated current.***

OPERATIONAL & FAILURE CONSIDERATIONS

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21)

> *17.7.4 Fast current update: This may be required for applications where the heading needs to be changed quickly e.g. mono hull MODUs or the direction of the current forces changes quickly. This needs to be used with caution as the natural time constant of the DP loop in systems with model control is about 15 to 20 minutes. This time lag has been acceptable in most situations as a vessel responds slowly and the sea current typically changes slowly (wind compensation is feed forward). Fast current update decreases the time taken to 'learn' about a new situation****. It should be recognized that any improper use of fast current update can cause instability and other problems. This feature should not be used to compensate for lack of external force compensation mode.***

LESSONS LEARNT FROM DP EVENTS DGNSS (SIC) & NEW DEVELOPMENTS IN LAST 5 YEARS

DP Event Bulletin	ITEMS
DP Event Bulletin 01/22 – April 2022	Case Study – Force off Position

TENSION SENSOR

Some vessels under DP control experience a variety of external forces which need to be compensated. 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 touch-down 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 pipe feed tension values back to the DP system. Thus, the DP system and DPO can manage the thrust requirements enabling compensation. Other 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 by the DP as false current. In most cases these forces will not act like a force due to current for example when pipelaying if the vessel moves ahead, but the pipe is not ready to be deployed (i.e. held stationary) then the S catenary shape extends and picks up pipe off the seabed. The force increases rapidly, and it is similar but opposite if the vessel moves aft. The control system must deal with these rapidly fluctuating forces differently to the slow changing DP current.

OVERVIEW, ADVANTAGE, DISADVANTAGE

External Force Compensation: When pipelaying, hook-up of mooring lines etc., horizontal forces are exerted on the vessel. Vessels undertaking industrial missions where such forces can be experienced should be equipped with means for external force compensation. Reliance on the DP control system treating such forces as 'learned' environment has and resulted in loss of position incidents with significant consequences.

The input of forces values for external force compensation can be manual or instrumented. Systems designed to provide and accept input from instruments should be subjected to a robust fault tolerant and fault resistant systems engineering approach. Sensible limits should be applied to these inputs to avoid the DP control system responding to erroneous values.

OPERATIONAL & FAILURE CONSIDERATIONS

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21)

> *17.8 EXTERNAL INTERFACES*
>
> *17.8.1 Sometimes a vessel's industrial mission requires the DPCS to be interfaced to other equipment that can affect the positioning of the vessel such as **pipe tensioners, hawser tension**, draught sensors or fire monitors. If external interfaces of this nature are required then a careful system engineering approach should be implemented. This should consider redundancy and failure modes. In addition to error checking functions provided by redundancy, the acceptable signal ranges should be carefully bounded/limited to be within a realistic range.*
>
> *19.1 SYSTEMS ENGINEERING APPROACH*
>
> *19.1.1 The vessels industrial mission may require the DPCS to be interfaced with non-station keeping related equipment (For example, pipe tensioners, riser tensioner stroke, draught sensors or fire monitors). Design of such interfaces should follow a system engineering approach and may result in a degree of complexity that was not initially envisaged. Examples of systems engineering approaches are FMEA and consequence analysis.*

ABS Guide For Dynamic Positioning Systems 2021 states that

> *External Force Compensation: Where the measured external force acting on the vessel, which is separate from the environment, is included in the DP calculation and treated as a force feed forward. This mode is used to account for pipe tensions in a pipe laying vessel and hawser tension in a shuttle tanker.*

LESSONS LEARNT FROM DP EVENTS TENSION SENSOR AND NEW DEVELOPMENTS IN LAST 5 YEARS

None available

DRAFT SENSOR OVERVIEW

A draft sensor is used to measure the depth of water below the vessel. The draft sensor is typically mounted on the hull of the vessel and can measure the depth of the water in real-time. Normally there will be several sensors fwd, midships, aft and sometimes on both port and starboard.

On Semi subs these measurements assist the ballasting process, and for the DP system it can change the underwater and above water areas used in the model / force calculation for wind and current. In the DP system this can probably be input automatically from the sensors or overwritten manually. The other indication of draft is the mass of the vessel.

If it is possible to manually enter the draft (and it is significant for the vessel) then the 'DP draft' should be part of the DP Checklists.

ADVANTAGE, DISADVANTAGE OPERATIONAL & FAILURE CONSIDERATIONS

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) explains that sometimes a vessel's industrial mission requires the DP control system to be interfaced to other equipment that can affect the positioning of the vessel such as pipe tensioners, hawser tension, **draught sensors** or fire monitors.

If external interfaces of this nature are required, then a careful system engineering approach (FMEA) should be implemented. This should consider redundancy and failure modes.

LESSONS LEARNT FROM DP EVENTS DRAFT SENSOR AND NEW DEVELOPMENTS IN LAST 5 YEARS

None available

DP System Computer, Controllers, Network, IJS
General
DP System Computer, Controllers - Overview inc. controllers & operator stations
DP System Computers and controllers- Lessons learnt from DP Events
Mode changes (Auto to Manual, etc.) - considerations and lessons from DP station keeping events
IJS Overview
Rules & guidance
Power supplies - Redundancy philosophy
Location of control station
Exercises & Drills

IMO MSC/Circular 1580 states that a DP system must include a DP control system and that a DP control system consist of:

.1 computer system/joystick system;

.2 sensor system(s);

.3 control stations and display system (operator panels);

.4 position reference system(s);

.5 associated cabling and cable routeing; and

.6 networks.

We recommend that you access IMO MSC/Circular 1580 and read it in full. The following points explain general elements of a DP control system as required by IMO MSC/Circular 1580.

3.4 DP control system

3.4.1 General

.1 In general, the DP control system should be arranged in a DP control station where the operator has a good view of the vessel's exterior limits and the surrounding area.

.2 The DP control station should display information from the power system, thruster system and DP control system to ensure that these systems are functioning correctly. Information necessary to safely operate the DP system should be visible at all times. Other information should be available upon the operator's request.

.3 Display systems and the DP control station in particular should be based on sound ergonomic principles which promote proper operation of the system. The DP control system should provide for easy accessibility of the control mode, i.e. manual joystick, or automatic DP control of thrusters, propellers and rudders, if part of the thruster system. The active control mode should be clearly displayed.

.4 For equipment classes 2 and 3, operator controls should be designed so that no single inadvertent act on the operator's panel can lead to a loss of position and/or heading.

.5 Alarms and warnings for failures in all systems interfaced to and/or controlled by the DP control system should be audible and visual. A record of their occurrence and of status changes should be provided together with any necessary explanations.

.6 The DP control system should prevent failures being transferred from one system to another. The redundant components should be so arranged that any failed component or components may be easily isolated so that the other component(s) can take over smoothly with no loss of position and/or heading.

.7 It should be possible to control the thrusters manually, by individual levers and by an independent joystick, in the event of failure of the DP control system. If an independent joystick is provided with sensor inputs, failure of the main DP control system should not affect the integrity of the inputs to the independent joystick.

.8 A dedicated UPS should be provided for each DP control system (i.e. minimum one UPS for equipment class 1, two UPSs for equipment class 2 and three UPSs for equipment class 3) to ensure that any power failure will not affect more than one computer system and its associated components. The reference systems and sensors should be distributed on the UPSs in the same manner as the control systems they serve, so that any power failure will not cause loss of position keeping ability. An alarm should be initiated in case of loss of charge power. UPS battery capacity should provide a minimum of 30 minutes operation following a main supply failure. For equipment classes 2 and 3, the charge power for the UPSs supplying the main control system should originate from different power systems.

.9 The software should be produced in accordance with an appropriate international quality standard recognized by the Administration.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) makes some interesting observations on the selection of a DP control system at the vessel design stage. It suggests that DP control systems tend to receive less attention and scrutiny during the design phase but that lack of attention at this early stage can introduce vulnerabilities that can impact the industrial mission of the vessel.

It also suggests that a vessel designed with control systems with enhanced redundancy over the minimum requirements may be desired to increase operational uptime of the vessel's industrial mission.

Note: Example of the above is a triple redundant controller system being limited by the provision of two power supplies. However, if three power supplies are provided, the full benefit of the redundancy can be realised.

MTS DP VESSEL DESIGN PHILOSOPHY GUIDELINES - APP B (Rev2 - Apr21) offers the following diagram of a DP control system. It is worthy of consideration. It shows a typical DP2 systems with the two redundancy groups (Red and Green) which is generally dictated by which UPS each item is powered from.

In this case the 'networks' are internal to the system as the I/O for the Thrusters and power system interface are centralised.

In other vessels the DP will share the networks with a Vessel Management System (VMS) then the I/O is distributed.

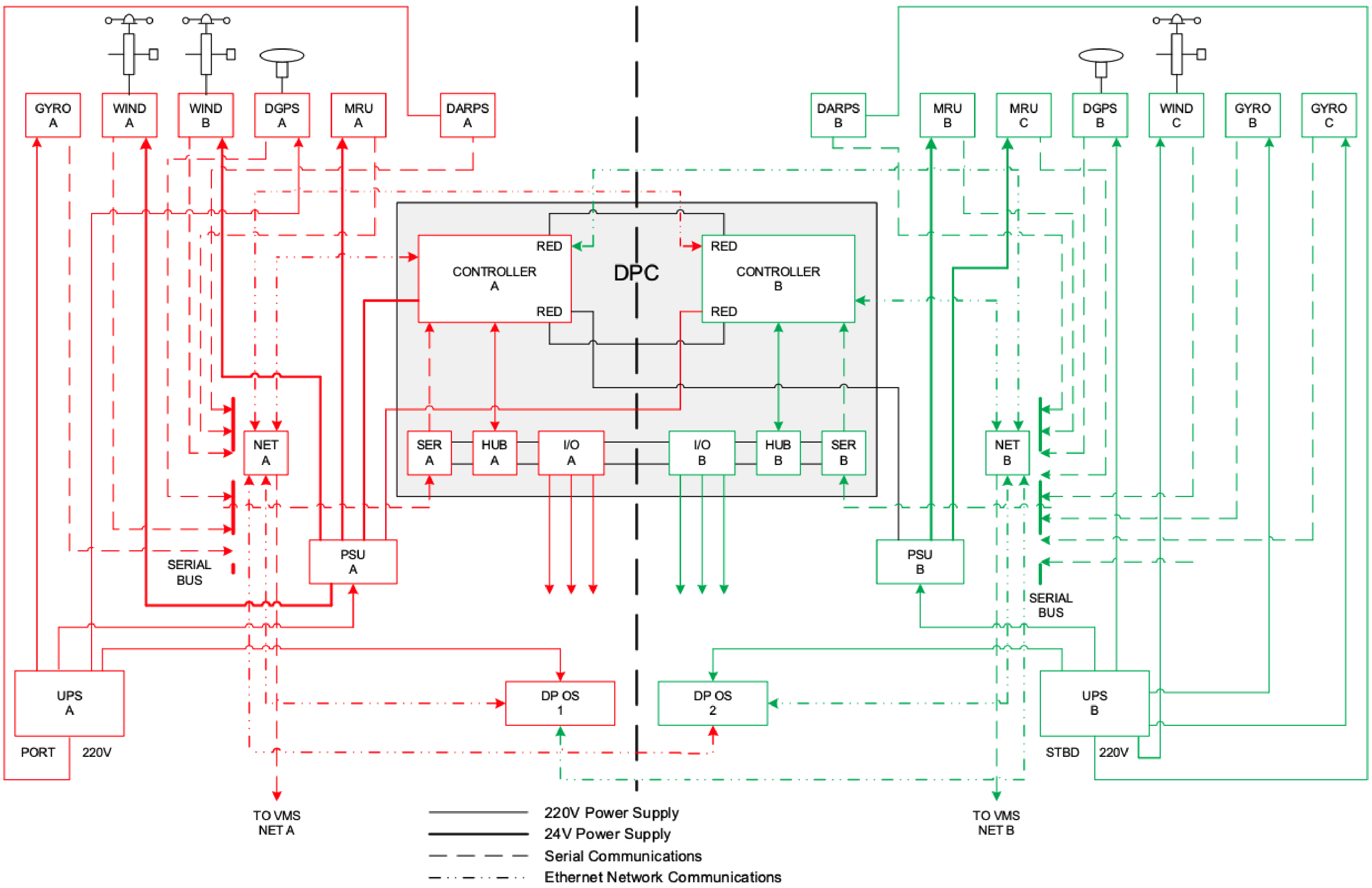


Figure 32 - MTS DP VESSEL DESIGN PHILOSOPHY GUIDELINES - APP B (REV2 - APR21)

PRACTICAL ONBOARD EXERCISE

Access your vessel's FMEA and consider the DP control system diagram

IMO MSC/Circular 1580 states

3.4.2 Computers

.1 For equipment class 1, the DP control system need not be redundant.

.2 For equipment class 2, the DP control system should consist of at least two computer systems so that, in case of any single failure, automatic position keeping ability will be maintained. Common facilities such as self-checking routines, alignment facilities, data transfer arrangements and plant interfaces should not be capable of causing failure of more than one computer system. An alarm should be initiated if any computer fails or is not ready to take control.

.3 For equipment class 3, the main DP control system should consist of at least two computer systems arranged so that, in case of any single failure, automatic position keeping ability will be maintained. Common facilities such as self-checking routines, alignment facilities, data transfer arrangements and plant interfaces should not be capable of causing failure of more than one computer system. The two or more computer systems mentioned above do not include the backup computer system; thus, in addition, one separate backup DP control system should be arranged, see paragraph 3.4.2.6. An alarm should be initiated if any computer fails or is not ready to take control.

.4 For equipment classes 2 and 3, the DP control system should include a software function, normally known as "consequence analysis", which continuously verifies that the vessel will remain in position even if the worst-case failure occurs. This analysis should verify that the thrusters, propellers and rudders (if included under DP control) that remain in operation after the worst-case failure can generate the same resultant thruster force and moment as required before the failure. The consequence analysis should provide an alarm if the occurrence of a worst-case failure were to lead to a loss of position and/or heading due to insufficient thrust for the prevailing environmental conditions (e.g. wind, waves, current, etc.). For operations which will take a long time to safely terminate, the consequence analysis should include a function which simulates the remaining thrust and power after the worst-case failure, based on input of the environmental conditions.

.5 Redundant computer systems should be arranged with automatic transfer of control after a detected failure in one of the computer systems. The automatic transfer of control from one computer system to another should be smooth with no loss of position and/or heading.

.6 For equipment class 3, the backup DP control system should be in a room separated by an A-60 class division from the main DP control station. During DP operation, this backup control system should be continuously updated by input from at least one of the required sets of sensors, position reference system, thruster feedback, etc. and be ready to take over control. The switchover of control to the backup system should be manual, situated on the backup computer, and should not be affected by a failure of the main DP control system. Main and backup DP control systems should be so arranged that at least one system will be able to perform automatic position keeping after any single failure.

.7 Each DP computer system should be isolated from other on-board computer systems and communications systems to ensure the integrity of the DP system and command interfaces. This isolation may be effected via hardware and/or software systems and physical separation of cabling and communication lines. Robustness of the isolation should be verified by analysis and proven by testing. Specific safeguards should be implemented to ensure the integrity of the DP computer system and prevent the connection of unauthorized or unapproved devices or systems.

PRACTICAL ONBOARD EXERCISE

We recommend that you access IMO MSC/Circular 1580 and read it in full. The entire document is only 21 pages long and forms the bases of all DP operations.

IMO MSC/Circular 1580 defines a DP control station as

> *a workstation designated for DP operations, where necessary information sources, such as indicators, displays, alarm panels, control panels and internal communication systems are installed (this includes: DP control and independent joystick control operator stations, required position reference systems' Human Machine Interface (HMI), manual thruster levers, mode change systems, thruster emergency stops, internal communications).*

Building on the fact that DP control stations should be based on sound ergonomic principles which should provide for easy accessibility of the control mode IMO MSC/Circular 1580 defines how DP control stations should be arranged and what equipment they should contain:

> *3.1.8 The DP control station should be arranged where the operator has a good view of the vessel's exterior limits and the surrounding area. Equipment that should be located at the DP control station includes, but is not limited to:*
>
> *.1 DP control and independent joystick control operator stations;*
>
> *.2 manual thruster levers;*
>
> *.3 mode change systems;*
>
> *.4 thruster emergency stops;*
>
> *.5 internal communications; and*
>
> *.6 position reference systems' HMI, when considered necessary.*

IMCA M103 suggests that control station design should apply best ergonomic practices and be positioned such that adjacent surface structures, vessels, appropriate working areas and vessel operations are visible from the control station so that the DPO can effectively monitor vessel positioning performance.

The DP control station should be positioned such that the DPO is provided with as large an arc of external visibility as is compatible with the requirements for physical protection of the control station. CCTV images of working areas may be used where provision of direct visibility is not possible.

IMCA M103 states that the following information should be displayed at the control station as applicable:

- *position reference system status and configuration;*
- *survey data for surface and seabed features, overlaid with the vessel outline and ROV position;*
- *a similar display positioned to be visible from the independent joystick control position in the event of a failure of automatic control;*
- *CCTV images of working areas not visible from the control position, overside, back decks and cranes and adjacent vessels or structures when in close proximity;*
- *ROV, diver and crane camera images as appropriate;*
- *status of industrial mission systems (for example, pipelay, dredge, rock placement, cable lay and repair and crane systems);*
- *positions and tracks of other vessels operating in the vicinity;*
- *gangway status, crane position and loads, vessel draught, ballast system status;*
- *riser monitoring information;*

- *for accommodation vessels, a plot showing the outline of the adjacent facility, overlaid with the accommodation vessel outline and gangway position; the outlines should represent the area where any contact would first occur following an inability to maintain position;*
- *vessel position footprint in relation to the tanker loading facility, and the permitted sectors for operation (defined limits for position and heading);*
- *telemetry data (where available) from the tanker loading facility, including relative position information, ESD status and mooring hawser tension;*
- *vessel draught, cargo loading and ballast system status;*
- *CCTV images of manifolds, mooring systems and the separation distance from the offshore tanker loading facility.*

and that independent communication facilities to monitor and communicate with simultaneous activities/locations should be provided where appropriate.

FIGURE 33 - K MASTER BRIDGE CHAIR WORKSTATION

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Event Bulletin 03/17	Both DP operating stations stopped communication – DP incident
DP Event Bulletin 02/21 – June 2021	Human Factor Caused a DP Undesired Event
IMCA DP Station Keeping Bulletin 03/19 September 2019	Operating outside DP equipment class 2 requirements – DP incident
IMCA DP Station Keeping Event Bulletin 01/18 February 2018	Unintentional deactivation of the DP system – DP incident
IMCA DP Station Keeping Event Bulletin 02/16 June 2016	Differences between operator stations

MODE CHANGES (AUTO TO MANUAL, ETC)

MSF 182 states that,

> *There may be occasions during a normal supply operation when it is appropriate to change over from auto DP control to joystick/manual control. In this case the vessel will revert to conventional supply vessel mode and will be subject to appropriate controls. Where the vessel transfers control from DP to manual or conventional control, transfer back to DP control should be subject to a repeat of location set up checks.*

IMCA M117 stresses the importance of

> *Practical training including handling and manoeuvring the vessel on manual, joystick and automatic control and changing between modes of operation*

The Guidelines for Offshore Marine Operations suggest that

> *Whenever control of a vessel is transferred to another station or a different operating mode is selected it should be ensured that all manoeuvring arrangements are responding as anticipated prior to undertaking any operations in the close proximity of an offshore facility, another vessel or other obstruction.*
>
> *In all cases changes in operating mode from position keeping to passage making should not take place within 1.5 ship's lengths of the facility if departing from the lee side, or within 2.5 ship's lengths if departing from the weather side. Furthermore, if departing from the weather side such changes in operating mode must only be implemented in a drift off position.*

CONSIDERATIONS AND LESSONS FROM DP STATION KEEPING EVENTS

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21)

> *17.23 JOYSTICK SENSITIVITY*
>
> *17.23.1 DP and IJS joysticks can command large amounts of thrust over a very small lever range. Joysticks are usually provided with two settings:*
>
> *1. A 'fine control' setting is provided to improve the sensitivity of control when manoeuvring.*
>
> *2. A 'full control' setting is used when high power is required.*
>
> *17.23.2 Design should consider default selection to 'full control' setting when control is transferred from DP mode to joystick.* ***There have been known incidents where the operator has transferred to joystick control to pull away from a platform as an emergency measure but failed to realize that the joystick was still in 'fine control' setting.***

IMCA M103tells us that the means by which control over the thrusters is changed from manual to DP to independent joystick (IJS) is a potential weak point in any DP system. No failure of the selector system should prevent manual control. See also ISJ Overview.

The control selector forms a common point between all thrusters. The design should ensure that a failure cannot cause the control mode to transfer from auto DP to another mode. For DP equipment class 3 vessels it is important to ensure no single failure of the control selector switch should cause control to transfer unexpectedly to the backup DP system. This can be achieved by having a separate digital communications interface from the control selector to each thruster field station.

Accidental change of mode continues to be a cause of DP incidents. Locating buttons with critical functions close to less critical functions increases the risk of a critical button being accidentally pushed. Good ergonomic design should position critical push buttons where they are unlikely to be operated inadvertently.

EXERCISE SCENARIO	AUTO/MANUAL - HUMAN INTERVENTION

Objective:

To familiarise all vessel crew what the consequences of switching essential DP equipment into Local/manual whist in auto DP.

There have been many event reports submitted that have detailed the effects of switching running equipment into local/manual, mainly because the effects of doing so were unknown, carrying out this drill will enable the Key DP Personnel to further understand the consequences of their actions.

Method:

This test can be undertaken when the vessel is in a safe open space with no risk of excessive position excursion causing an unsafe condition.

Vessel in auto DP

1. **Thrusters:**
   - At local position switch thruster into local – Observe effect on DP control – Reinstate.
   - At local thruster lever control switch thruster to manual– Observe effect on DP control – Reinstate.
2. **Engines:**
   - At local position switch engine into local – Observe effect on DP control – Reinstate.
   - At remote engine control switch thruster to manual– Observe effect on DP control – Reinstate.
3. **Pumps:**
   - At local position switch running seawater pump into local – Observe effect on SW system – Reinstate. (Carry out for all systems pumps).
   - At local position switch running freshwater pump into local – Observe effect on FW system – Reinstate. (Carry out for all systems pumps).
   - At local position switch running fuel pump into local – Observe effect on SW system – Reinstate.
4. **DP Controllers:**
   - On running/in use controller, reset – Observe effect on DP control – Reinstate.

Observations During Drill:

1. Does the action effect the DP Control?
   Are the expected alarms generated?
2. Are the systems affected and how?
3. Document all the effects.

EXERCISE SCENARIO	AUTO/MANUAL - HUMAN INTERVENTION

Discussion Points (Post exercise):

Vessel

- Are all effects understood?

Human Factors

- Are all effects understood with regards Human intervention?
- What should be the response of the DPO?
- What would be the worst-case scenario?
- Discuss the alternative actions/reactions that may occur in response to a similar scenario. Are there multiple paths to a successful resolution or is there a preferred solution? Why?

Review of DPO and other key DP personnel reaction

- What potential gaps in the existing DP Familiarisation program have been highlighted as a result of the exercise?
- What changes/revisions should be considered for the training and familiarisation procedures?

Review the applicable checklists (ASOG CAM/TAM/DP operations Manual/bridge and engine room checklists/ FMEA/DP Annual Trials programmes/etc.)

- What additional necessary actions and considerations should be addressed?
- What potential changes should be made to make the checklists more appropriate?
- What additional necessary operating conditions and parameters should be considered?
- What potential changes should be considered to make Decision Support Tools more applicable to the vessel and her equipment?
- How would these changes improve/affect the vessel's capabilities and limitations?

Conclusion:

Based on the results of the exercise and related discussions before and after, any suggestions for follow up including any corrective actions deemed appropriate should be accurately detailed and managed to close out.

Handling of essential DP systems in the correct manner requires knowledge of the Key DP Personnel and how the DP system reacts to human intervention.

Items to consider include:

- DP system reaction to failures.
- Appropriateness of communication.
- Training requirements.

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Event Bulletin 01/18 February 2018	Unintentional selection of manual mode – DP incident
IMCA DP Station Keeping Bulletin 03/18 August 2018	Case study – Switching to manual mode caused loss of position.

RULES & GUIDANCE

Remembering that IMO MSC/Circular 1580 states that a DP control system includes an independent joystick system it also requires that

> *.7 It should be possible to control the thrusters manually, by individual levers and by an independent joystick, in the event of failure of the DP control system. If an independent joystick is provided with sensor inputs, failure of the main DP control system should not affect the integrity of the inputs to the independent joystick.*

And requires the independent joystick (ISJ) to be

> *independent of the automatic DP control system should be arranged. The power supply for the independent joystick system (IJS) is to be independent of the DP control system UPSs. An alarm should be initiated upon failure of the IJS.*
>
> *3.7.2 The IJS should have automatic heading control.*

The IJS, with auto heading control, can be used to control the vessel through its independent connection to the thrusters if the DP control system fails. The IJS should be powered from an uninterruptable source of power independent of the DP control system. It should be arranged to allow rapid transfer of control from the DP control system. Consideration should be given to provide an independent means for the operator to monitor vessel position.

POWER SUPPLIES - REDUNDANCY PHILOSOPHY

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) reiterates IMO MSC/Circular 1580

> *15.6 INDEPENDENT JOYSTICK AND MANUAL CONTROLS*
>
> *15.6.1 These should not use the same networks as used by the DP system to transmit its thruster command to the thrusters etc. However even if a separate transmission path is used there may still be shared components at the local thruster control systems. From this perspective it is very important that network storm protection is effective to prevent the thruster control systems being disabled by the storm thereby disabling the IJS.*
>
> *17.2 INDEPENDENCE OF 'INDEPENDENT' JOYSTICK AND MANUAL CONTROLS*
>
> *17.2.1 The independent joystick and manual controls should be truly independent of the DPCS* (DP Control System) *with direct connection to the thrusters control electronics or thruster outstation/process station. IJS and Manual Controls should not send thruster commands over the same networks as the DPCS.*

Consider this extract from the FMEA of a DP 2 vessel.

> *INDEPENDENT JOYSTICK SYSTEM*
>
> *6.7.1 A independent joystick system is available as a backup if the DP system fails. The control cabinet located XXX and receives main 120V supply from the 120V Panel L3 and backup 24V from UPS 4. The IJS provides automatic heading control and wind compensation while controlling of all available thrusters from a joystick.*
>
> *6.7.2 The IJS receives input from the below position and environmental sensors, however the IJS is not capable of Auto DP. The IJS can also be used as an autopilot.*
>
> - *Gyro 1 Interface from Gyro 1 main unit*
> - *Wind 1 Interface via the wind serial splitter*
> - *DGPS 1 Interface from the DP 21 computer*

6.7.3 Communication from the independent joystick system operator terminal is sent to each thruster outstation via a direct hardwired link. Thus the independent joystick system is considered an emergency control system if all other DP network communication fails.

6.8 FAILURE MODES OF INDEPENDENT JOYSTICK SYSTEM

6.8.1 The DP control system and the IJS have the thruster Field Stations in common. There is a risk that in the event of a severe network disturbance (network storm), the processors in the Field Station could be disabled and would not default to the hardwired interface.

LOCATION OF CONTROL STATION

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21)

21.6.6 The arrangement and layout of the main DP control station should follow the logic and orientation of the visual field if applicable. For example, directional controls such as levers, joysticks etc. should be aligned such that pushing the lever aft moves the vessel aft.

EXERCISES & DRILLS

EXERCISE SCENARIO	ACTION REQUIRED DURING A DRIVE OFF FROM POSITION

7. What is the duration from commencement to concluding a safe outcome for the vessel?
8. Was the communication effective during the drill?

Actual results witnessed:

EXAMPLE:

The vessel maintained accurate station keeping with remaining online equipment.

The DP system reacted well maintaining station keeping as did the crew's reaction and response to the failure….

The vessel DP system regained control returning to original position.

Discussion Points (Post exercise):

Human Factors

- What are the potential risks due to "multi-tasking" during DP operations that may directly lead to the scenario outlined during this drill? (Examples include managing / monitoring deck operations, radio traffic, etc.)
- What are the potential risks due to distractions in the workspace (i.e., Bridge, Engine Room) that may directly lead to the scenario outlined during this drill? (Examples include routine maintenance procedures, social media, personnel interactions, etc.)
- Discuss the alternative actions/reactions that may occur in response to a similar scenario. Are there multiple paths to a successful resolution or is there a preferred solution? Why?
- Following a review of the simulated exercise and the vessel and crew's reaction, what different operator (Bridge and/or ECR) reaction(s) might be warranted if faced with a similar situation during operation?

Review of DPO and other key DP personnel reaction

- What potential gaps in the existing DP Familiarisation program have been highlighted as a result of the exercise?

  What changes/revisions should be considered for the training and familiarisation procedures?

Review the applicable checklists (ASOG CAM/TAM/DP operations Manual/bridge and engine room checklists/ FMEA/DP Annual Trials programmes/etc.)

- What additional necessary actions and considerations should be addressed?
- What potential changes should be made to make the checklists more appropriate?
- What additional necessary operating conditions and parameters should be considered?
- What potential changes should be considered to make Decision Support Tools more applicable to the vessel and her equipment?
- How would these changes improve/affect the vessel's capabilities and limitations?

Conclusion:

Based on the results of the exercise and related discussions before and after, any suggestions for follow up including any corrective actions deemed appropriate should be accurately detailed and managed to close out.

Handling of vessel in the correct manner requires knowledge of the DP specific equipment, how the DP system reacts to scenarios and their respective alarms and the human intervention required if necessary to ensure station keeping. Items to consider include:

a. Appreciation of the potential to stop a thruster in emergency cases using the emergency stops
b. How quickly would it be determined that this scenario constituted a "red" situation within the ASOG

EXERCISE SCENARIO	ACTION REQUIRED DURING A DRIVE OFF FROM POSITION

c. DP system reaction to multiple failures
d. What to look for on the operator stations
e. What event and alarms indicate any system failures
f. Methods of fault finding and investigation
g. Appropriateness of communication
h. Training requirements

Backup DP Transfer Switch Functionality

Target audience for this LFI

- Vessel Management and Operations Teams on DP Vessels
- DP Technical Support, Vessel Owners/Contractors
- FMEA providers
- Classification Societies / DP Approval Authorities

What happened

During a DP control transfer drill, the Emergency changeover switch from 'Main' DP to 'Backup' DP system, located in Engine Control Room (ECR), was observed to be out of alignment. The decision was made to make the switch correction when the vessel was not in DP, so as to have adequate risk controls in place.

Later, in preparation for the task, the vessel was in Independent Joystick (IJS) mode. The DPO set up the DP backup system in standby mode as an additional barrier. When the changeover switch was turned from 'Main DP to 'Back up DP' position, control of the propulsion was transferred from IJS to DP Backup.

Why it happened

Control of Thrusters was transferred from IJS to DP backup system. All thrusters reduced the load to the demand setup in the Backup DP system (zero thrust).

The DP system has a NetIO signal telling the Thruster controllers directly that the backup has taken command. The purpose of this is to bypass the bridge utility panels in case the bridge is no longer usable. Upon the reception of this signal, the Thruster system will force the command of each thruster to DP mode. The DP in turn, will be controlled by the backup DP system, since the transfer switch is in backup mode.

In the VMS thruster module there is a configurable parameter called "Auto DP Mode", this bit is normally set to 1 by the DP vendor during installation. When set to 1 and Backup DP switch is selected, the thruster will transfer to the Backup DP regardless of the mode (i.e. DP, IJS, Lever, Auto pilot) selected.

Lessons learned

1. Limited information on the full functionality of the changeover switch in the vendor manual. The manual references only transfer from Main DP to Backup DP.
2. FMEA and other DP tests have been focused on transferring from Main DP system to Backup DP only. The full functionality of the switch had not been tested in navigational mode.
3. Training centers, OJT and drills are focused on transferring from Main DP to Backup DP.

Recommendations

It is recommended that owners of DP vessels disseminate this LFI to Vessel Management Teams on all DP vessels and vendors of DP FMEAs and to their DP Technical Support Function.

Actions

Vessel owner updated OJT and assessment program to include detail information on the full functionality of the Emergency Backup DP switch. Owner also sent out a Technical Information Bulletin to the DP fleet with the following actions:

1. When the vessel is disconnected from the seabed (between wells) and operations allow:
    a. Confirm the Main/Back-Up DP Mode Selector Switch has a plexiglass cover and the switch knob screw is well tightened, utilizing a “Loctite” type material preventing becoming loose.
    b. Confirm transfer condition on every station (Thruster manual levers, cJoy, conning station (auto pilot mode) and DP). All modes must transfer thruster control to the Backup DP station when the switch is turned to back-up DP. Notify Engineering and Marine Assurance group if test results are different.
2. Ensure the Main/Back-Up DP Mode Selector Switch is tested as part of field arrival trials as indicated in policy.
3. Confirm DPOs have a good understanding of the risk associated with this switch, that in the event that someone unexpectedly turns this switch, all thruster controls will be transferred from bridge to the back-up DP station, therefore vessels shall place a Caution sign by the selector switch as displayed below.

MTS DP COMMITTEE THANKS THE SUBMITTER OF THIS LFI ON BEHALF OF THE DP COMMUNITY. LFI’s ARE PUBLISHED ON THE MTS DP COMMITTEE WEBSITE TO PROMULGATE LEARNINGS FROM INCIDENTS WITH A VIEW TO ENABLE PROACTIVE MANAGEMENT OF SUCH VULNERABILITIES AND MINIMIZE POTENTIAL FOR DP LOSS OF POSITION INCIDENTS.

Power and Power generation Systems and UPS
General
Power Management (e.g. General requirements / impact of mission equipment (e.g. effect on station keeping capability), operating within capability)
Blackout Prevention
Load dependent Starting & stopping of power generation
Power generation - basics of frequency & voltage control (active & reactive power)
Open and Closed Bus operation
Short circuit testing
Power limit – As per IMO 1580
Hybrid Battery systems - Guidance, concept, principles, risks
UPS - following redundancy, the requirements of operation
DC Grids
Lessons Learnt

IMO MSC/Circular 1580 states that

1.2.11 Dynamic Positioning system (DP system) means the complete installation necessary for dynamically positioning a vessel comprising, but not limited to, the following sub-systems:

.1 power system;
.2 thruster system; and
.3 DP control system.

And that a

1.2.19 Power management system means a system that ensures continuity of electrical supply under all operating conditions.

1.2.20 Power system means all components and systems necessary to supply the DP system with power. The power system includes but is not limited to:

.1 prime movers with necessary auxiliary systems including piping, fuel, cooling, pre-lubrication and lubrication, hydraulic, pre-heating, and pneumatic systems;

.2 generators;
.3 switchboards;
.4 distribution systems (cabling and cable routeing);
.5 power supplies, including uninterruptible power supplies (UPS); and
.6 power management system(s) (as appropriate).

Power is a critical consideration in DP vessel design and operation because the concept of redundancy is based on power and propulsion systems that are independent in respect of single point failures. That is to say, no defined single point failure in one redundancy group will disrupt the operation of any of the others.

The simplest diesel electric redundancy concepts have two fully redundant power and propulsion systems, each capable of maintaining position and heading if the other fails. More complex designs make use of multiple systems each providing partial redundancy such that the vessel can maintain position with all combinations of independent systems that survive any defined failure. For example, a vessel with three systems can hold position with any two of the three systems available.

An advantage of redundancy concepts based on multiple independent systems, each providing partial redundancy, is that provided each system has all necessary services required to support DP it is possible to consider these systems as providing full redundancy in reduced environmental conditions. Thus, a DP system with three independent power and propulsion systems can still be considered fault tolerant if only two of the three systems are available and may be able to continue DP operations in this degraded condition if environmental conditions allow.

IMO MSC/Circular 1580 states that the power system should have an adequate response time to changes in power demand and defines the power system redundancy requirements for each equipment class as follows:

3.2.2 For equipment class 1, the power system need not be redundant.

3.2.3 For equipment class 2, the power system should be divisible into two or more systems so that, in the event of failure of one sub-system, at least one other system will remain in operation and provide sufficient power for station keeping. The power system(s) may be run as one system during operation, but should be arranged by bus-tie breaker(s) to separate the systems automatically upon failures which could be transferred from one system to another, including, but not limited to, overloading and short circuits.

3.2.4 For equipment class 3, the power system should be divisible into two or more systems so that, in the event of failure of one system, at least one other system will remain in operation and provide sufficient power for station keeping. The divided power system should be located in different spaces separated by A-60 class divisions. Where *the power systems are located below the operational waterline, the separation should also be watertight. Bus-tie breakers should be open during equipment class 3 operations unless equivalent integrity of power operation can be accepted according to paragraph 3.1.4.*

3.2.5 For equipment classes 2 and 3, the power available for position keeping should be sufficient to maintain the vessel in position after worst-case failure according to paragraph 2.2.

3.2.6 For equipment classes 2 and 3, at least one automatic power management system (PMS) should be provided and should have redundancy according to the equipment class and a blackout prevention function.

3.2.7 Alternative energy storage (e.g. batteries and fly-wheels) may be used as sources of power to thrusters as long as all relevant redundancy, independency and separation requirements for the relevant notation are complied with. For equipment classes 2 and 3, the available energy from such sources may be included in the consequence analysis function required in paragraph 3.4.2.4 when reliable energy measurements can be provided for the calculations.

3.2.8 Sudden load changes resulting from single faults or equipment failures should not create a blackout.

Paragraph 3.2.3 implies that when running a DP2 system closed bus the bus tie would be the critical protective element. However, this is a very simplistic view as it does not consider the consumers and the effects of a bus fault on them etc. On many vessels the voltage dip due to a serious fault would be enough to trip thruster drives and so whilst you may end up with two separate groups following the opening of the bus tie, you may not have any thrusters running on either bus!

POWER MANAGEMENT

A power management system (PMS) on a DP vessel is a system that controls, supervises and manages the distribution of electrical power on the vessel, ensuring the efficient and safe operation of all electrical equipment and systems. This may include monitoring and controlling the main generator sets, emergency generator sets, and electrical loads on the vessel, and managing the transfer of power between different sources to ensure continuous and reliable power supply.

The use of the word 'ensuring' may be a bit optimistic as in practice we still hear of vessels with sophisticated power management systems suffering blackouts!

IMCA M103describes a PMS as

> *2.17.1 Power Management System (PMS)*
>
> *The power management system (PMS) is an essential protective system and a common point connecting segregated power systems. The PMS plays a critical role in the ability of the power plant to respond to load changes and can control load demands so as to avoid disturbances in the power system. If a DP vessel is operated with sufficient spinning reserve then there will be a large margin for load acceptance and rejection and as such the system will have a higher degree of resilience to load fluctuations.*
>
> *In some designs the PMS functions are limited to generator management and blackout recovery, such an approach removes many of the concerns regarding the PMS being a common failure point.*
>
> *2.17.2 PMS Hardware*
>
> *Power management systems should utilise distributed control systems with redundant data communications links and should include a power feed from an uninterruptible power supply (UPS). The UPS for each PMS should have a primary supply from the same redundant power system which it controls as well as a supply from the emergency switchboard. The UPS should include a manual selector switch to transfer onto the emergency switchboard supply.*
>
> *Redundant groups of machinery and equipment should be provided with their own PMS which may be further subdivided to control generators and switchboards. The PMS for each redundant group should be capable of managing that power system independently both when isolated from other groups and when connected with other groups in a closed bus tie configuration. The interface between the PMS for different groups should use a master–master philosophy in preference to master–slave arrangements.*
>
> *PMS operator stations and field stations should be provided in a manner that is consistent with the redundancy concept.*

(E.G. GENERAL REQUIREMENTS / IMPACT OF MISSION EQUIPMENT (E.G. EFFECT ON STATION KEEPING CAPABILITY), OPERATING WITHIN CAPABILITY)

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) Chapter 14 on offers some detailed guidance power and vessel management systems and we recommend you read this in full.

It states that,

> *14.10.1 Most power management systems provide protective functions. These should be tested periodically to have a high degree of confidence that they will operate on demand.*
>
> *14.10.2 Design of power management systems should ensure that failure effects do not exceed the worst-case failure design intent. Furthermore, design should endeavour to minimize the number of failures which have effects equal to the worst-case failure effect.*
>
> *14.10.3 Design should follow the principles of independence and redundancy to the extent feasible. For the purpose of this section, independence means that failure of a PMS function or hardware should not result in the loss of more than one generator or thruster.*

14.10.4 Redundancy requirements for PMS systems:

1. At least two PMS operator's stations.
2. Field stations for generators, thrusters, safety systems and switchboards should have dual processors.
3. Field stations for generators, thrusters, safety systems and switchboards should have dual power supplies.
4. There should be one field station for each bus section in the main power generation. Failures should leave switchgear configured as set and not cause a change of state.
5. There should be one field station for each thruster and generator.
6. Failures of generator field stations should leave the generator running as set.
7. Field stations for auxiliary systems should be provided in line with the divisions in the redundancy concept. I/O from an auxiliary system's field station for control of DP related pumps and valves should not cross the divisions in the redundancy concept.
8. Field stations and I/O for vessel safety systems should be provided in line with the divisions in the redundancy concept.
9. In field stations for engine control and safety systems control, the safety functions should reside in different hardware (processors and I/O modules).

14.10.5 It is accepted that I/O interfaces to items of main machinery are not redundant.

14.10.6 Care should be taken when assigning I/O and fail-safe settings on data acquisition cards within field stations. There have been several cases where power management systems have used faulty generator circuit breaker status (frozen) to attempt load sharing on generator that was no longer connected. The result was a severe reduction in bus frequency followed by phase back of all thrusters and loss of position.

14.10.7 In order to enable transparency in PMS/VMS configurations, control systems should be supplied with Instrument Loop Diagrams as per Instrument Society of America Standard ISA-5.4-1991, or equivalent international standard (i.e. IEC, DIN, etc.)

In the absence of Loop diagrams, wiring diagrams offer limited value in operational phase of the vessel.

The DP control system is continuously monitoring the power available to the thrusters and should not order more thrust than there is generating capacity to support. It is the task of the vessels DPOs and engineers, supported by the power management systems, to ensure that sufficient generating capacity is made available to the DP control system for thrust demand. This is normally done by ensuring there is adequate spinning reserve so that any fault will not cause a power deficit. Whilst standby sets can be ready for load dependent starting. This will only replenish spinning reserve margin following the fault. There is always a chance that the standby engines have a hidden fault and will fail to start, to connect, to load up etc.

All parties need to be aware that the Industrial mission of the vessel may assigning the same power priority to some industrial consumers as those required for station keeping.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) stats that

The identification of such industrial mission consumers should be analysed, rationalized and appropriately addressed in the Power Management System.

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Bulletin 03/19 September 2019	DP3 drillship switchboard blacked out – DP undesired event

IMO MSC/Circular 1580 requires equipment classes 2 and 3 to have

> *at least one automatic power management system (PMS) should be provided and should have redundancy according to the equipment class and a blackout prevention function.*

And that

> *Sudden load changes resulting from single faults or equipment failures should not create a blackout.*

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) We recommend that you read this document in full and chapter 14.14 in particular for information on black out prevention.

> *14.14.1 Power priority: In diesel electric power plants there may be a need to prioritize power to the most important consumers. The thrusters and the auxiliary systems that service them are usually the most important consumers and if there is a need to shed load to prevent blackout these are the last to be affected.*
>
> *Consumers associated with the industrial mission are normally the first to be shed unless integrity of power supply is to be maintained for safety reasons or to prevent potential escalation. Example power to drawworks designed for active heave compensation (additional information on active heave compensation is provided below). Designs should strive to ensure adequate power margins are available to supply station keeping and safety critical industrial consumers.*
>
> *It may also be possible to identify a large amount of non-essential load associated with heating, HVAC and ventilation that could be shed first if problems occur.*
>
> *Stored energy systems that can provide short term power from large battery banks are likely to play and increasingly important role in blackout prevention.*

The DP redundancy concept is based on having enough power sources connected such that if one generator or one bus section is lost that there is still sufficient power and thrust to maintain position and heading. This should not require additional generation in the short term. Obviously IF other engines are available to start then this should be done to restore the running spinning reserve.

Practically the load on the system will be fluctuating as demands change. However, IF there is a loss of power due to a fault AND the load on the remaining engines causes an overload then there are various blackout prevention strategies that may come into play.

First would be 'load shedding' this tends to be a PMS function that can shut down noncritical loads if the engines are heading for an overload condition.

A second strategy is that the PMS is monitoring the engine load and is sending this information to some of the Industrial mission equipment and probably the thrusters. It may be that the Industrial mission equipment is programmed to phase back, slow down, pause etc to allow the engines to recover. If the load is still high, it may be that the thruster drives also will limit the load. The goal is to try to not make a bad situation worse, by overloading / stalling the remaining engines.

A further strategy is that some drives are monitoring the input frequency from the power system. If the frequency is falling the implication is that the engine is overloaded (but could also be fuel or air starvation etc) when the drive sees the frequency falls below a certain value, it will phase back and reduce its power demand.

One other strategy is that the DP is also monitoring the power consumption on each bus section and if it sees an overload it will reduce its demand to the thrusters.

In several of the cases above the action of saving the remaining engines may result in a lack of enough thrust to hold heading and position. However, if the strategies are coordinated correctly the thrusters will get priority once the engine output has returned below the MCR.

The ASOG/WSOG, TAGOS, DP operation manual etc should offer power strategies that should avoid such situations.

However, it is not a perfect world and blackouts do occur from time to time.

We might define blackouts in the following way:

Complete vessel blackout – all the thrusters are stopped, whatever generation that was running has tripped etc. This is a very critical failure as the vessel can no longer hold position, and the critical off position depends on many factors and is largely dependent on the operation and direction and speed of drift.

Partial Blackout – one bus section or one redundancy group has been lost. In this case the vessel should still hold position and heading and is capable of control to allow termination of the operation and moving to a place of safety. For a drill ship connected to the riser it is about restoring the redundancy. Some vessels refer to this as a brown out.

The above imply a sharp cut in supply (i.e. a CB opening) but with individual engines running it is possible to have a slow blackout, i.e. the voltage drops slowly due to some AVR control fault, or the frequency falls due to a fuel issue. The implication is that a single engine is running then the vessel is in open bus so the blackout if it comes only affects a single redundancy group.

Are you aware of the blackout prevention strategies implemented on your vessel?

BLACKOUT DETECTION

IMCA M103offers some guidance on blackout detection

> *Blackout detection should be robust: false detection of blackout could create a blackout. Detection should be based on several independent sources such as voltage transducers, blackout relays and generator circuit breaker status.*
>
> *Tripping of generator circuit breakers or other circuits on detection of blackout should be left to dedicated blackout protection relays.*

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) expands on good design practice for effective blackout detection. Again, we recommend you read this document in full.

> *14.14.4 Blackout detection: It is important that the methods used to detect blackout are reliable and that they do not operate spuriously particularly if the first action of the blackout recovery system is to open all the generator circuit breakers before proceeding to reconnect them.*
>
> *Design should facilitate use of several methods to confirm there has been a blackout including blackout relays, voltage and frequency transducers. However, the diversity provided by this multiple detection scheme can be negated if all detection methods connect to one bus VT.*
>
> *It is good practice to provide suitable delays to prevent a voltage dip initiating a blackout recovery sequence. Even in power systems with adequate voltage dip ride through it is acknowledged that voltage dips may result in the loss of some auxiliary systems. In such circumstances, it may be desirable for the power management system to restart them. This task should be assigned to a different function from the main blackout recovery function.*
>
> *The preferred method to reduce the consequences of spurious blackout recovery is to limit the actions of the power management system to starting of consumers and rely on individual protection functions within generators and consumers to disconnect any transformers, faulty circuits and unwanted loads prior to restart.*
>
> *There have been known and published vulnerabilities experienced in designs that 'clear the board' as a precursor to blackout recovery. Such designs need the highest level of blackout detection reliability.*

BLACK OUT RECOVERY

IMO MSC/Circular 1580 states that there must be a black out recovery procedure in the vessel-specific DP operations manual (4.6.7). It is absolutely critical that you know and understand AND PRACTICE (DRILL) your vessel's blackout recovery procedure.

Note – Blackout recovery may well be a manual intervention and if so, it should be a 'practice drill' to ensure everyone understands their task to recover as quickly as possible.

IMCA M103offers some more detailed guidance on blackout recovery.

> *Blackout recovery systems should be designed to start all available generators on detection of blackout. All DP essential consumers supporting thrusters and generators should be capable of making themselves ready for DP operation automatically, without the need for supervisory control. Connection to the main power supply can be triggered by detection of the main power being available. Thrusters, main propellers and rudders used for DP should be made as independent as possible, autonomous thrusters can be designed to make themselves ready for DP system operation as soon as they detect that power is available.*
>
> *For vessels operating with bus ties closed there may be advantages in arranging for the bus ties to be closed again during blackout recovery but care is necessary in the design to prevent re-closing onto a fault.*

See also annual trails *The annual DP trial should test all functions on which the redundancy concept depends, including network testing, blackout recovery plans and ESD functions.*

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) expands further on blackout recovery system and tells us that a fully automatic blackout recovery system is not a class requirement. *Main class rules and SOLAS have requirements for some degree of automatic restart of electric power systems but for a DP vessel it may be unwise to rely on this to ensure a full blackout recovery system is provided.*

Adding batteries directly to the thrusters can provide propulsion capability during a power plant blackout even if the power distribution system is damaged or otherwise unavailable. See also Hybrid Battery systems - Guidance, concept, principles, risks.

Some guidance is offered in MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) on thruster starting sequences following a black out as follows,

> *The thruster blackout recovery sequence should be carefully designed to optimize starting time reliability. There may be a number of permissive, interlocks and safety shutdowns which can be configured. However, it is important that these are active only when necessary. For example, it may not be necessary to make cooling water flow a start permissive as the drive will later shut down on over temperature if the pumps fail to start. A large number of permissives may reduce the reliability and extend the recovery sequence. In a blackout recovery situation, auxiliary systems may become available at different times depending on the operation of the blackout recovery function. If the drive control system delays starting until auxiliaries become available, the time taken to make the thruster ready for DP can be excessively long or the starting sequence may fail.*

But they also offer a cautionary note for vessel's where the drive is not capable of starting with the propeller turning in forwards or reverse rotation.

> *During blackout recovery thruster propellers may be turning due to inflow. Drives without regeneration capability may experience starting problems if the drive is not capable of starting with the propeller turning in forwards or reverse rotation. If one or more thrusters fail to start then blackout recovery may be compromised. Most drives are capable of starting on-the-fly but the issue of starting with inflow should be clarified with the manufacturer.*
>
> *14.14.5 Automatic return of thrusters to DP: Modern protective functions have advanced to the point where automatic restart and selection of thrusters into DP following a blackout is recommended. This aids in arresting*

vessel motion with minimum operator intervention. Some designs will halt automatic reselection of thrusters once vessel motion has been stopped.

14.14.6 Independence from emergency switchboard: Blackout recovery should not depend on the emergency switchboard or the emergency generator.

Blackout recovery should be possible with the emergency switchboard and emergency generator unavailable at least for a reasonable period of time. It is acknowledged that beyond a reasonable amount of time blackout recovery may need to depend on the emergency switchboard and generator to provide needed auxiliary systems.

TESTING BLACKOUT RECOVERY

The critical point is that all DP personnel must know, understand, and practice their vessel's blackout recovery process.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) again offers some detailed guidance

When testing automatic blackout recovery systems, it is important to trip the last generator not just shut it down or E-Stop it. This is a more realistic test as most diesel electric vessels blackout with the generators still running but not connected. The test protocol should be appropriately defined taking into consideration the characteristics of the power system. For example, it may be necessary to prevent the tripped generator immediately reconnecting depending on what type of simulated fault was used to trip it. It may be possible to push the lock-out button or simply hold down the CB open button.

Some blackout recovery systems have failed to operate when tested in under realistic failure scenarios even though they have worked perfectly in scenarios where the last engine was emergency stopped or manually shut down. Ideally, blackout recovery should be tested in the following scenarios.

- *Recover from all engines stopped.*
- *Recovery from engines running but generator circuit breakers tripped.*

Independence of the blackout recovery system from the emergency generator or switchboard should be established by testing and documented to prove the design (Starting of the emergency generator to be inhibited).

Tests should be conducted to validate full and partial blackout recovery on power plants operating in open and closed bus configurations.

The blackout recovery may well start the thrusters but the DPOs need to know if they need to intervene to re-select them back into the DP system.

IMCA offer the following DP Emergency Drill Scenario

including their failure modes.

EXERCISE SCENARIO   RECOVERY FROM FULL BLACKOUT

Objective:

To familiarise all vessel crew with what actions are required in order to recover the vessel into a controllable condition.

Method:

This test does not have to be a live test unless a safe manageable situation presents itself. A workshop should be conducted onboard.

1. Discuss what would be the first reaction upon blackout
   - How was the blackout triggered? This may change how the recovery is conducted.
   - What operations are being conducted?
   - Will personnel be directly at risk?
   - Are there still full communications?
   - Can operations be terminated?
2. Recovery – ECR - Restore Power
   - Is there a flow chart in the ECR that can be followed?
   - Will generators auto start and connect?
   - What machinery is locked out?
   - How are Generators and thrusters re-set – are there any auxiliaries that require re-setting as part of start permissive?
3. Recovery - Bridge – Secure Vessel Position & Minimise Excursion
   - Where is the vessel drifting?
   - What coms remain live most important ECR-Bridge?
   - Is there a flow chart on the Bridge that can be followed?
   - What is required in order to start the thrusters?
   - Are thrusters automatically selected into DP Control or manually?
   - Is there a clear escape route?
4. Mission Personnel – Prevent Uncontrolled Damage to Personnel, Environment and assets
   - Considerations as to how the mission personnel react to secure their equipment and communicate with Bridge.
   - How does the mission equipment react upon power up (Clamps/brakes etc.)

Observations During Workshop:

1. Is the DP emergency drill procedure being followed?
2. Are those individuals directly involved in the exercise reacting appropriately given their assigned duties?
3. Are those individuals indirectly involved reacting in an appropriate manner?
4. Is the degree of participation and diligence as expected?

EXERCISE SCENARIO	RECOVERY FROM FULL BLACKOUT

Discussion Points (Post exercise):

Human Factors

- What are the potential risks due to "multi-tasking" during DP operations that may directly lead to the scenario outlined during this drill? (Examples include managing / monitoring deck operations, radio traffic, etc.)
- What are the potential risks due to distractions in the workspace (i.e., Bridge, Engine Room) that may directly lead to the scenario outlined during this drill? (Examples include routine maintenance procedures, social media, personnel interactions, etc.)
- Discuss the alternative actions/reactions that may occur in response to a similar scenario. Are there multiple paths to a successful resolution or is there a preferred solution? Why?
- Following a review of the simulated exercise and the vessel and crew's reaction, what different operator (Bridge and/or ECR) reaction(s) might be warranted if faced with a similar situation during operation?

Review of DPO and other key DP personnel reaction

- What potential gaps in the existing DP Familiarisation program have been highlighted as a result of the exercise?

  What changes/revisions should be considered for the training and familiarisation procedures?

Review the applicable checklists (ASOG CAM/TAM/DP operations Manual/bridge and engine room checklists/ FMEA/DP Annual Trials programmes/etc.)

- What additional necessary actions and considerations should be addressed?
- What potential changes should be made to make the checklists more appropriate?
- What additional necessary operating conditions and parameters should be considered?
- What potential changes should be considered to make Decision Support Tools more applicable to the vessel and her equipment?
- How would these changes improve/affect the vessel's capabilities and limitations?

Conclusion:

Based on the results of the exercise and related discussions before and after, any suggestions for follow up including any corrective actions deemed appropriate should be accurately detailed and managed to close out.

Handling of power system failures in the correct manner requires knowledge of the DP specific critical equipment required for vessel control, how the DP system reacts to multiple failures and alarms and the human intervention required if necessary to ensure station keeping. Items to consider include:

- Awareness of the power system segregation (following the redundant groups)
- DP system reaction to multiple failures
- Mission equipment reaction to power loss and power up
- Appropriateness of communication
- Training requirements

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Bulletin 03/19 September 2019	DP3 drillship switchboard blacked out – DP undesired event
DP Event Bulletin 01/23 – January 2023	Case Study – Closed Bus – Knowing the Risks
DP Event Bulletin 03/21 – August 2021	DP Emergency Drill Scenario RECOVERY FROM FULL BLACKOUT

ABOVE AND BEYOND

MTS have developed a TechOp to promote good practice in the design and testing of automatic blackout recovery systems for DP vessels, TECHOP (D-03 - Rev1 - Jan21) BLACKOUT RECOVERY and we suggest you read this in full.

Even though most DP Class notations do not specifically require automatic blackout recovery it is universally accepted as a risk reduction measure for all DP operations where the consequences of loss of position are unacceptable.

There have been a number of high profile DP incidents in which the automatic blackout recovery system failed to restore power and propulsion despite being routinely tested with satisfactory results. TECHOP (D-03 - Rev1 - Jan21) BLACKOUT RECOVERY seeks to alert system designers to potential design flaws and provide guidance on desirable features.

LOAD DEPENDENT STARTING & STOPPING OF POWER GENERATION

See also Spinning Reserve

Load dependent starting refers to a method of starting a generator that is triggered by the amount of load, or demand, being placed on the system. In other words, the starting process is tailored to the specific load conditions of the bus at any given time.

The main advantage of load dependent starting is that it allows for a more efficient and cost-effective starting process, as the generator can be started in a manner that matches the load conditions. This can help to reduce wear and tear on the generator, as well as minimize the amount of time it takes to start and stabilize the generator.

IMO MSC/Circular 1580 states that *sudden load changes resulting from single faults or equipment failures should not create a blackout.*

Sudden increases in load can be created by

- changes in the environmental conditions (gusts, squalls, solitons, etc.);
- executing a change of position or heading;
- demand from industrial consumers;
- use of the DP joystick;
- drive off associated with position jump;
- a run-away thruster.
- Engine trips
- Bus section fault

Studies should confirm the levels of spinning reserve required to provide active redundancy. Load dependent starting should ensure such margins are preserved under **all operating conditions**.

Please note that PMS systems normally allow engines to be allocated a priority for LDS. They do not generally consider the redundancy implications. For example, in closed bus, 3 RGs 1 engine required on each bus section. Then one engine has a problem and LDS triggers the next in priority to start, so we may end up with 2, 1 and 0 across the bus sections. In fact, we only know which engine to start when we know which engine has a problem.

If it is to do with a load increase we may need to start 2 engines (for redundancy) rather than overall load condition.

In open bus condition rather than use LDS it may be better to use minimum engines per bus?

What is the configuration on your vessel?

LOAD BALANCE

Demand from industrial consumers can be considerable. The 'load balance' indicates the load on the generators for the DP system, hotel services, AND the industrial mission.

It is important that the load balance acknowledges requirements for the DP system to have active redundancy i.e. ability maintain position with the machinery that remains available following the worst case failure. It is important that the load balance reflects the configurations that will be used for DP including operating in CAM mode and TAM mode.

When the power plant is configured as a common power system all generators can feed all loads. There may be significant currents across the bus ties if loads are not equally divided up amongst the main switchboards.

It is therefore important to balance DP system loads and those associated with the vessel's industrial mission and necessary hotel services.

LOAD SHARING

Generators operating in parallel in a common power system would normally share kW load in proportion to their rating so that the full capacity of the power plant can be reached without any one generator overloading first. Failure to ensure balanced load sharing can result in one generator becoming overloaded leading to cascade failure and blackout or limiting the amount of power to less than the capacity of the power system.

There are various methods of load sharing. We recommend that you read MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) for more detail.

Speed droop is a term used in power generation to describe the reduction in engine or generator speed that occurs when the load on the generator increases. It is a control strategy for each engine governor that allows multiple engines to operate in parallel without any communication between them.

In a generator set, the speed droop is usually expressed as a percentage of the rated engine speed, and is used to control the speed v output power of the engine. For example, a generator with a 5% speed droop will reduce its speed by 5% when the load on the engine increases from zero to 100%. The amount of speed droop can be adjusted by changing the governor settings but is normally fixed at commissioning. However, some systems are described as 'compensated droop' where the PMS can change the setpoint in each engine. See next section

Speed droop is an important characteristic of power generators because it helps to ensure that the generator operates within its safe operating range, and that the frequency is inversely proportional to the load on the engine. Note that the frequency of the grid is directly proportional to the speed of the generators connected to it.

LOAD SHARING BY COMPENSATED DROOP

Mechanical governors used in early marine diesel electric plant were operated in uncorrected speed droop mode. These mechanical governors were less accurate than their modern digital counterparts and relatively large differences in the load carried by each generator could develop.

Power management systems were used to trim out the difference to restore load sharing and correct the frequency across the entire load range. PMS control of the governors is affected by way of 'raise' and 'lower' contacts which drive the governor speed set point up and down to balance the load and maintain frequency.

These contacts are now useful to keep the system frequency closer to the nominal, but also allow uneven load sharing if that is required.

The advantage of droop is that there are no cross connections between the engines in different redundancy groups and so we know that no faults can cross the boundaries due to the governors.

LOAD SHARING BY ISOCHRONOUS LOAD SHARING SYSTEMS

The advent of electronic governors driving electro mechanical actuators for fuel control allowed the development of isochronous load sharing using analogue or digital load sharing lines. In this method of load sharing the governors operate in constant speed mode rather than speed droop. In constant speed mode the generators do not naturally share load and slight differences in speed set-point caused by measurement and control errors leads to one generator taking the entire system load.

In isochronous mode, information on the load being carried by each generator is passed to all other generators to make them share load equally. If the load sharing lines fail, a severe load sharing imbalance will develop and blackout may follow. Connectors can fall out, wire can break or even short circuit, all these failure modes should be considered.

Generally an Isochronous load share strategy must have a 'fall-back position' to prevent the imbalance described above occurring.

LOAD SHARING BY SPEED DROOP

The advent of accurate digital governors has allowed a return to the use of uncorrected speed droop mode without the disadvantages inherent in the old mechanical and hydraulic governors. Accurate load sharing can now be obtained with minimal speed droop using these types of governors.

This arrangement has the fewest number of failure modes and does not rely on the power management system for trimming nor does it depend on protective functions to transfer operating mode to speed droop.

There are governor failure modes that can destabilize the power plant and protective functions are required to subdivide the common power systems or trip the faulty generators to prevent blackout. Vessels which are not at risk from this type of failure by virtue of operating their power plant as two or more independent power systems can still benefit from protective functions which reduce the risk of losing more than one generator on the same power system.

Loss of multiple generators on one independent system is an undesirable failure effect even if the integrity of the other systems is maintained as it may impact the industrial mission. Some vendors have developed protective functions that can be implemented on power systems operating in uncorrected speed droop.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) notes

> *Failure to full fuel is always an undesirable failure mode but it should only succeed in causing a blackout of a common power system if the system load is less than the rating of the faulty generator. The adoption of variable speed thruster drives makes this condition more likely, and very large vessels can DP in benign conditions at very low load. Thruster bias can be used to increase the systems load as mitigation. It is difficult to reconcile burning large amounts of fuel as a protective function with an environmentally conscious policy.*

Thruster bias, as a method of protection, may be defeated by load shedding systems that act on the overload of a single generator. It is far better to detect the kW load imbalance that would occur and identify the failed governor control and trip that engine before it can affect the 'system'. It should be noted that the ratio of generator rating to system/bus load increases with subdivision of the power system. The risk of partial blackout is increased by designs operating as multiple subdivided power systems. The risk of partial blackout may be acceptable in preference over the consequence of a full blackout. To mitigate against partial and full blackouts, protective functions associated with governors and AVRs are recommended for open and closed bus power system configurations.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) reiterates

> *that integrity and success of open bus power system operation is dependent upon the engines performing to their rated capacity. Maintenance objectives should be geared to achieving this.*

It is reiterated that integrity and success of open bus power system operation is dependent upon the engines performing to their rated capacity. Maintenance objectives should be geared to achieving this.

IMCA M103states

> *Designing the power system to run in uncorrected speed droop can minimise potential common point fault propagation paths, accuracy and stability in this mode of operation are well within the capability or modern digital governors. The use of electronic governors with a backup mechanical governor was once considered to offer benefits, however experience in DP vessels suggests that backup mechanical devices caused more incidents than they prevented.*

LOAD SHEDDING

The traditional means of preventing an overload and consequential blackout caused by loss of generating capacity was to operate the power plant with sufficient spinning reserve to cope with a loss of generating capacity. However, the poor load step response of some modern engines and large industrial consumers makes this impractical and other measures, such as load shedding, are required.

The most effective form of load shedding is provided by variable speed drive control systems for thrusters and other rotating machinery, also known as **phase-back**.

Phase back is a method utilized to temporarily reduce power consumption following an event, to stabilize the power plant and avoid a black-out.

MTS DP VESSEL DESIGN PHILOSOPHY GUIDELINES - APP B (Rev2 - Apr21) note that,

> *There has been a noticeable reduction in failure rates of thrusters since the introduction of variable frequency drives (VFDs) with fixed pitch propellers. VFDs facilitate fast phase back capability, a key feature to prevent power plant instability.*

The phase back function attempts to maintain an acceptable bus frequency during overload conditions. This method of load shedding has several advantages:

- **Independence**: Each drive makes the decision to shed its load independently of the others reducing the risk of control system failure leading to the loss of more than one thruster.
- **Continuity**: This function allows time for the power system to recover by connecting standby generators. Phase back is reduced as the power plant recovers.
- **Integrity**: By basing the phase back function on frequency rather than power the integrity of the load shedding function is not dependent on an assumed generator capacity. Thus, the system will act in response to failures that cause the generators to slow down such as fuel or combustion air problems.
- **Maximum capacity**: Systems based on maintaining acceptable bus frequency provide access to whatever power is available from the plant even if generators are only capable of reduced capacity.
- **Load acceptance**: The phase back system can compensate for poor load acceptance in modern medium speed diesel engines. This may be required if the step loads associated with power system faults are greater than the load acceptance rating of the engines.

POWER MANAGEMENT SYSTEM (PMS)

Diesel electric vessels traditionally have Power Management Systems (PMS) designed to ensure there are always sufficient generators online to cope with increasing power demand and to cope with the worst-case loss of generators (see also spinning reserve).

The PMS is an essential protective system and a common point connecting segregated power systems. The PMS plays a critical role in the ability of the power plant to respond to load changes and can prevent starting of large loads to avoid disturbances in the power system. If a DP vessel is operated with sufficient spinning reserve then there will be a large margin for load acceptance and rejection and as such the system will have a higher degree of resilience to load fluctuations.

IMCA M103states that

> *In some designs the PMS functions are limited to generator management and blackout recovery, such an approach removes many of the concerns regarding the PMS being a common failure point.*

Redundant groups of machinery and equipment should be provided with their own PMS. This may be subdivided to control generators and switchboards.

The PMS for each redundant group should be capable of managing that power system independently both when isolated from other groups and when connected with other groups in a closed bus tie configuration.

Diesel electric propulsion is now almost universal amongst medium and large DP vessels where a diesel engine drives an electrical generator which is connected to a motor driven propeller or thruster by way of an electric cable.

The generators are almost universally alternating current (AC) (50 or 60z), and motors may be fixed speed (AC) or variable speed direct current (DC) type, or variable speed AC if drives (converters and inverters) are included. The thrust developed by the propeller may be controlled by varying the speed of the motor, or by varying the pitch of the propeller. Such simple systems can still be found in certain applications but the vast majority of medium to large DP vessels have a diesel electric power plant based on the power station concept.

In the power station concept, electric power is provided by several synchronous alternating current generators operating in parallel. The generators are connected to switchboards by way of circuit breakers that allow the generators and loads such as thrusters, service transformers and motors to be connected and disconnected as required. Typical power plants have four, six or eight generators connected to two or more switchboards.

Consider the power distribution diagram below.

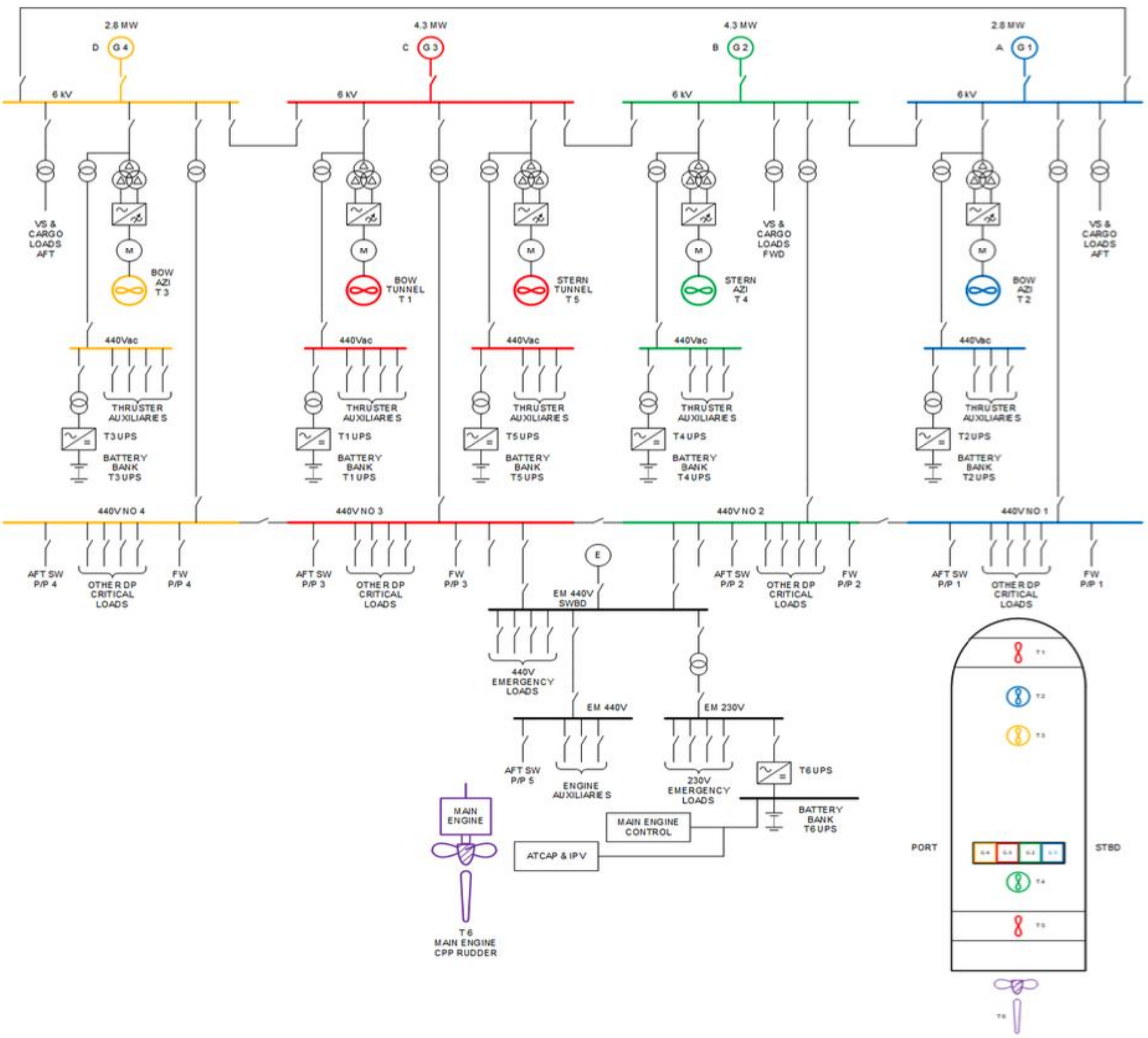


FIGURE 34 - MTS DP VESSEL DESIGN PHILOSOPHY GUIDELINES - APP B (REV2 - APR21)

Frequency control and voltage control are two separate aspects of electrical power generation, while active power and reactive power are two different types of electrical power. They are not the same thing,

Active power, also known as real power, is the portion of electrical power that is used to perform useful work, such as lighting, heating, or driving motors. It is measured in watts (W).

Reactive power, on the other hand, is the portion of electrical power that is needed to establish and maintain the magnetic field in electric motors, transformers, and other inductive loads (lagging current) but in any capacitive load (leading current). It is measured in volt-amperes reactive (VAR). Reactive power does not contribute to the useful work performed by the electrical system, but it is necessary for the proper functioning of many types of loads.

Remember that the amps (A) in kVA are real amps and they result in real heating in the devices and cables etc. So when an engine is rated at 1000kW and the alternator is rated at 1000kW at 0.8 pf it is 1250kVA. The load on the system determines the power factor (as this is where in simple terms the inductive load comes from). With the above DG set, if we have a load that is 1000kW but at 0.7 pf we will be correct to think that the engine can deliver 1000kW, however because the load is 0.7 pf it equates to approximately 1430kVA. The volts are the same so the current must be higher and in fact our alternator will overheat due to excessive current.

In an electrical power system, it is important to ensure the balance between active and reactive power to ensure that the alternators stay within their operational limits. Where systems suffer from poor power factor this can be 'corrected' using capacitors, which store and release reactive power, and through the proper design of the electrical system to minimize the amount of reactive power required. This is referred to as power factor correction.

With modern variable speed drives the load pf is normally better than 0.9 so this is less of an issue, but dc drives and some synchdrives etc at low loads can have very poor pf.

IMCA M 206 A Guide to DP Electrical Power and Control Systems has an in depth discussion on electrical power and control systems and we suggest you read it in full. It explains active and reactive power thus:

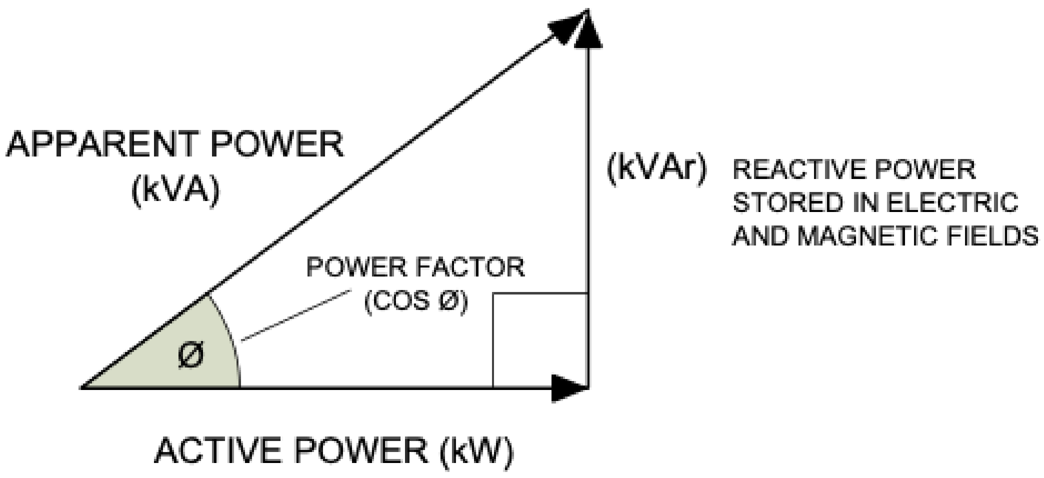


FIGURE 35 - KVA / KW / KVAR RELATIONSHIP

Power factor can vary between 0 and 1, with 0 representing an entirely reactive load and 1 representing an entirely active (resistive) load. Non-adjustable loads such as heaters will have unity power factor. Pumps and fans will usually have a power factor in the region of 0.85 at full load but it may be considerably lower at partial load. Loads which can vary the amount of active power they can draw from the generators (such as thruster motors) can have a variable power factor which improves as they draw more active power. Although reactive power does not directly equate to fuel consumption, the fact that additional generators need to be online to supply the reactive power means that there are additional losses associated with the inefficiency of running another generator just for this purpose. Power factor correction is the term applied to schemes intended to supply reactive power from sources other than generators to improve overall plant efficiency.

Particular care is required in applying power factor correction methods to marine power systems. In shore-based applications it is common practice to correct poor power factor by connecting static capacitor banks. In marine power systems this can have unexpected effects including creating system resonance leading to severe over voltage and equipment damage. The reliability of capacitors can also be an issue if they short circuit, creating a severe voltage dip on the power system. Other methods of power factor correction include synchronous condensers and active VAr compensation.

Frequency control in power generation on a dynamically positioned vessel refers to the process of maintaining a stable and constant electrical frequency in the power generation system. The frequency of the electrical power system is important because electrical devices are designed to operate at a specific frequency.

A common method of frequency control on a dynamically positioned vessel is using a governor system. The governor system monitors the speed of the engine and moderates fuel supply to maintain that nominal speed.

Voltage control in power generation on a dynamically positioned vessel refers to the process of maintaining a stable and constant electrical voltage in the power generation system. The voltage of the electrical power system is important because it affects the power delivered to the loads and the overall efficiency of the electrical system.

A common method of voltage control on a dynamically positioned vessel is using automatic voltage regulators (AVRs). The AVR monitors the voltage of the electrical power system and adjusts the voltage output of the generator to keep the voltage within a specified range.

In a dynamically positioned vessel, maintaining stable frequency and voltage is important for ensuring the proper operation of electrical equipment and for preventing damage to the electrical system.

Be aware that when a DG is running on its own the governor controls the speed (frequency) and the AVR controls the voltage. However, when two or more DGs are running in parallel connected to a common bus then they become 'coupled' by the system voltage and frequency. Now when an individual DG governor and AVR changes its settings the overall result on the system is a little different. In the case of three DG sets sharing the load, and then one engine fuel supply fails, that engine cannot contribute anymore so the other two must take up its load and work harder, but not only that they also have to keep the failed engine turning as the alternator now becomes a motor.

It is like three guys pushing a car at a constant speed, each of them is having to push with the same force. If one of them trips and falls down the other two must push harder to keep the speed the same. BUT it is not quite like that, in fact it is like they all have their hands glued to the car so when the one guy trips he must be dragged along by the car being pushed by the other two!

For the voltage the AVR is controlling the excitation of the alternator. Let us think about the 3 DGs again and now one AVR has a fault and thinks the voltage is low so wants to increase it. The way it would do that is to increase the excitation of its alternator. Now when the other two see the voltage rising, they think the opposite and therefore they reduce their excitation. Now the load pf has not changed so the sum of the alternator kVAs must still equal the load, so what happens is that the over excited alternator provides more current and the other two provide less current. So if they started at 0.8 pf then the failing AVR may cause it to go to 0.7 pf and the other two to 0.9 pf. At low loads this may well be within the capability of the alternators, but at higher loads it will be a problem and it is of course indicative of a fault that needs to be resolved.

SPINNING RESERVE

See also LOAD DEPENDENT STARTING & STOPPING OF POWER GENERATION

The term 'spinning reserve' is used to describe the difference between the system load and the online generating capacity. It does not include the capacity of standby generators.

It should be noted that this should be both kW and kVAR in systems where poor power factor could leave to excessive currents. It is worth noting that the pf pre WCF may not be the same as the pf post WCF.

It is good practice to maintain sufficient spinning reserve to cope with the worst case loss of power generating capacity without resorting to thruster phase back.

It may be impractical to carry sufficient spinning reserve to allow industrial consumers to continue without disruption and it may be acceptable to use load shedding functions to make power available for the thrusters.

This method of power plant operation can only be considered as contributing to redundancy and included in the consequence analysis if the load shedding function is sufficiently reliable.

Studies should confirm the levels of spinning reserve required to provide active redundancy. Load dependent starting should be programmed to ensure such margins are preserved under all operating conditions. See also Load Sharing and Balance.

POWER PLANT COMMON CAUSE FAILURES

TECHOP (G-02 - Rev1 - Jan21) POWER PLANT COMMON CAUSE FAILURES offers some typical common cause failures that can affect DP systems and may be overlooked in poor quality FMEAs including:

- *Common control system power supplies accepted on the basis that generators and thrusters fail 'as set' on loss of power. However, failure to low voltage is not analysed or tested and causes all generators and thrusters to trip.*
- *Common backup supplies to all generator and thruster control systems which fail to elevate voltage, damaging control systems leading to loss of position.*
- *Failing to provide excitation support for generators causes complete system blackout when generators are unable to provide enough fault current to clear a short circuit fault.*
- *Severe voltage dips associated with clearing short circuit faults from common power systems.*
- *Inappropriate design of earth fault protection which is not fully selective.*
- *Specifying inappropriate generator and power distribution system protection that is not selective and causes total blackout when the fault it is designed to act upon occurs.*
- *Protection relays left programmed with default settings and not those within the approved coordination study.*
- *Protective functions in thruster drives cause the drive to trip (or loss of DP ready signal) when the propeller regenerates power to the drive.*
- *High levels of power system transients and harmonic distortion.*
- *Basing all blackout protection on the assumed rated power (kW) capability of generators and failing to prove the generators are capable of rated capacity.*
- *Inadequate load acceptance and rejection performance in generators leading to unacceptable frequency excursions and power plant malfunction.*
- *Failing to consider the effects of poor power factor in power plant design.*
- *Environmental issues related to temperature and humidity levels of sensitive equipment locations. Provision of redundant HVAC and ventilation.*
- *Oil mist detectors for engines operating spuriously in some environmental conditions.*
- *Fuel contamination.*
- *Combustion air contamination.*
- *Blockage or fouling of common cooling water systems.*
- *Common software errors in redundant systems using identical controllers and software.*
- *Common vessel sensor principles.*
- *Inappropriate combinations of position reference system principles.*

A subset of common cause failures that can affect DP systems are related to **generator control systems** and the reaction of consumers to power system transients. Common cause failure mode related to generators and power distribution faults may include,

- *Generator excitation control faults – Severe reactive power imbalance – (over / under voltage).*
- *Generator fuel control faults- severe active power sharing imbalance (over / under frequency).*
- *Broken conductors and single phasing.*

- *Severe harmonic distortion and transient phenomena.*
- *Severe voltage dips associated with clearing short circuit faults anywhere on the power generation level or in the lower voltage distribution system.*
- *Overload / overcurrent due to loss of generating capacity.*
- *inrush transients.*
- *Under frequency caused by overload.*
- *Over and under frequency cause by inadequate load acceptance and rejection.*
- *Earth faults.*
- *Internal and external common cause failures such as fuel and combustion air contamination.*
- *For DP Class 3 vessels the colocation of non DP related consumers can introduce a common point into the power system design even though there is no electrical connection between equipment. Fire or flood damage can cause voltage dips on independent power systems serving the common space thus each independent power systems must have sufficient voltage dip ride through to prevent the malfunction of generators, thrusters and other essential consumers.*

Each of these failure modes can cause a severe power systems malfunction including loss of all thrusters and/or blackout. Power plant malfunction is typically caused by the failure mode adversely affecting the operating point of healthy generators such that they trip on their own protective functions. Thruster drives and service transformers may also trip on their own protection.

OPEN AND CLOSED BUS OPERATION

See section OPEN/CLOSED BUS OPERATIONS - RULES, GUIDANCE, CONSIDERATIONS, RISKS, CONFIGURATION - THE IMPORTANCE OF THE FMEA,

Dynamic positioning vessels with redundancy notations such as DPS-2 and DPS-3 have traditionally operated in an open (split) bus configuration for maximized redundancy. Recent changes to efficiency and emission regulations have driven DP operator preferences towards closed bus operation to enable operation with fewer generators online and at a higher percent loading to improve efficiency, reduce fuel consumption, decrease maintenance time/running hours, and reduce emissions. Marine pollution (MARPOL) regulation changes have pushed operators to operate fewer engines but at higher loading levels, which reduces emissions. Consequently, closed bus is the ideal configuration because the load can be shared among a minimum number of diesel-generator sets online as required to service the load.

IMO MSC/Circular 1580 stats that:

> *3.2.3 For equipment class 2, the power system should be divisible into two or more systems so that, in the event of failure of one sub-system, at least one other system will remain in operation and provide sufficient power for station keeping. The power system(s) may be run as one system during operation, but should be arranged by bus-tie breaker(s) to separate the systems automatically upon failures which could be transferred from one system to another, including, but not limited to, overloading and short circuits.*
>
> *3.2.4 For equipment class 3, the power system should be divisible into two or more systems so that, in the event of failure of one system, at least one other system will remain in operation and provide sufficient power for station keeping. The divided power system should be located in different spaces separated by A-60 class divisions. Where the power systems are located below the operational waterline, the separation should also be watertight. Bus-tie breakers should be open during equipment class 3 operations unless equivalent integrity of power operation can be accepted according to paragraph 3.1.4.*
>
>> *3.1.4 For equipment class 3, full redundancy of the control systems may not be possible. (i.e. there may be a need for a single changeover system from the main computer system to the backup computer system). Such connections between otherwise redundant and separated systems may be accepted when these are operated so that they do not represent a possible failure propagation path during DP operations. Failure in one system should in no case be transferred to the other redundant system.*

Where a power system is divided into two or more segregated systems then when using open bus ties, a loss of electrical power in one section should not lead to a loss of electrical power in any of the other sections This makes it unlikely that the vessel will suffer a total black out or lose all thrusters.

However, power systems can operate as a single power system with their bus ties closed. For a closed bus tie configuration to achieve the same level of redundancy as an open bus tie configuration it may be necessary to connect additional generators and to shed load in the event of loss of generating capacity (such as a generators trip) or if one part of the power system is lost.

Also remember that the vessel’s CAM may require the DP vessel to operate with open bus ties whereas its TAM may permit the vessel to operate with closed bus ties.

Both potential modes of operation have advantages and disadvantages which are summarised in IMCA M103as below

FIGURE 36 - FROM IMCA M103

	Open bus tie	**Closed bus tie**
Continuity of vessel DP operations	Good	Good
Station keeping integrity	Good	Good provided no critical failure modes occur
Flexibility for maintenance	Poor if all generators need to be connected at all times	Good
Fuel efficiency	Poor if all generators need to be connected at all times	Good
Emissions	Poor if all generators need to be connected at all times	Better than open bus tie systems

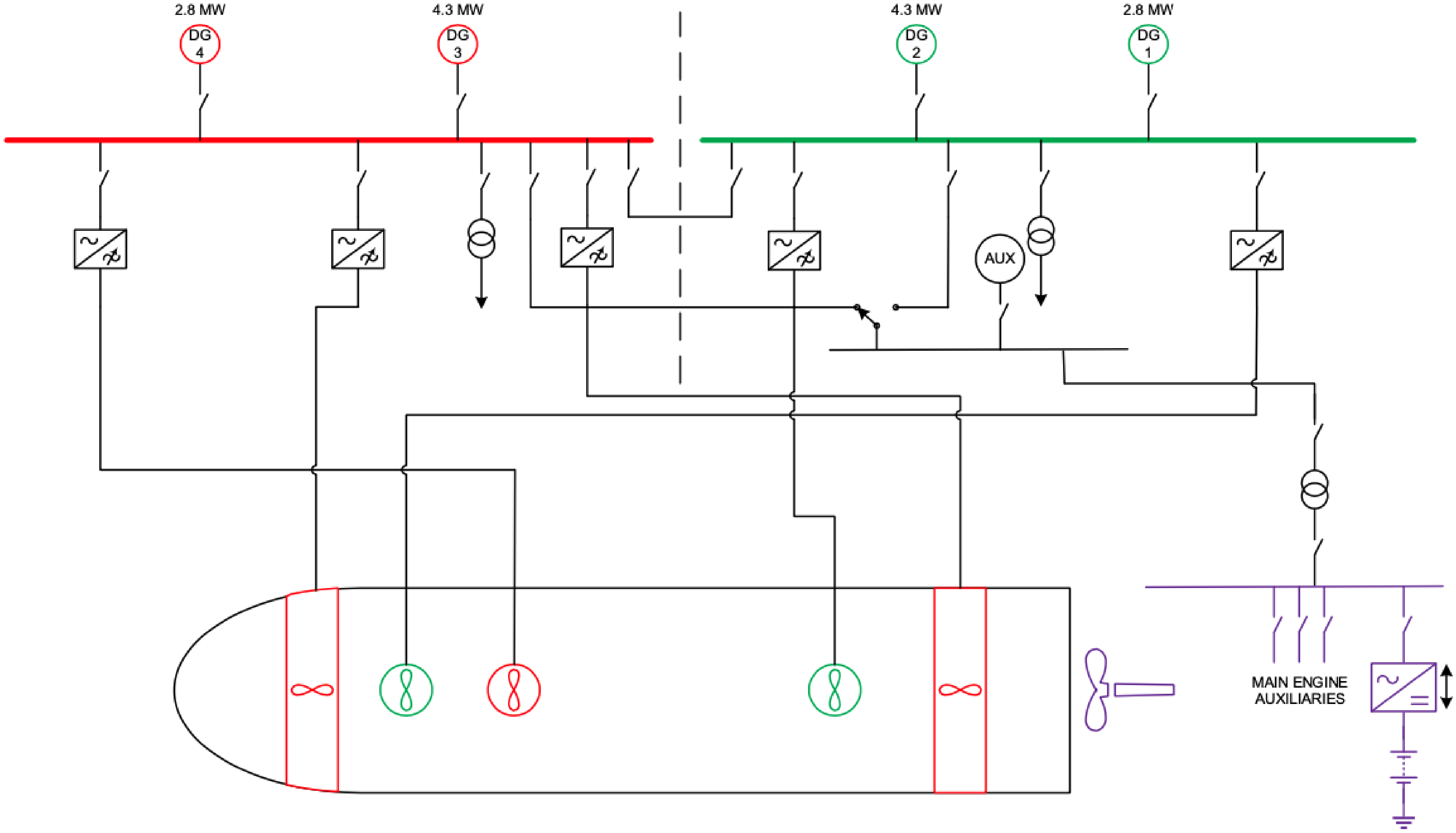


FIGURE 37 - REDUNDANCY TWO-WAY SPLIT

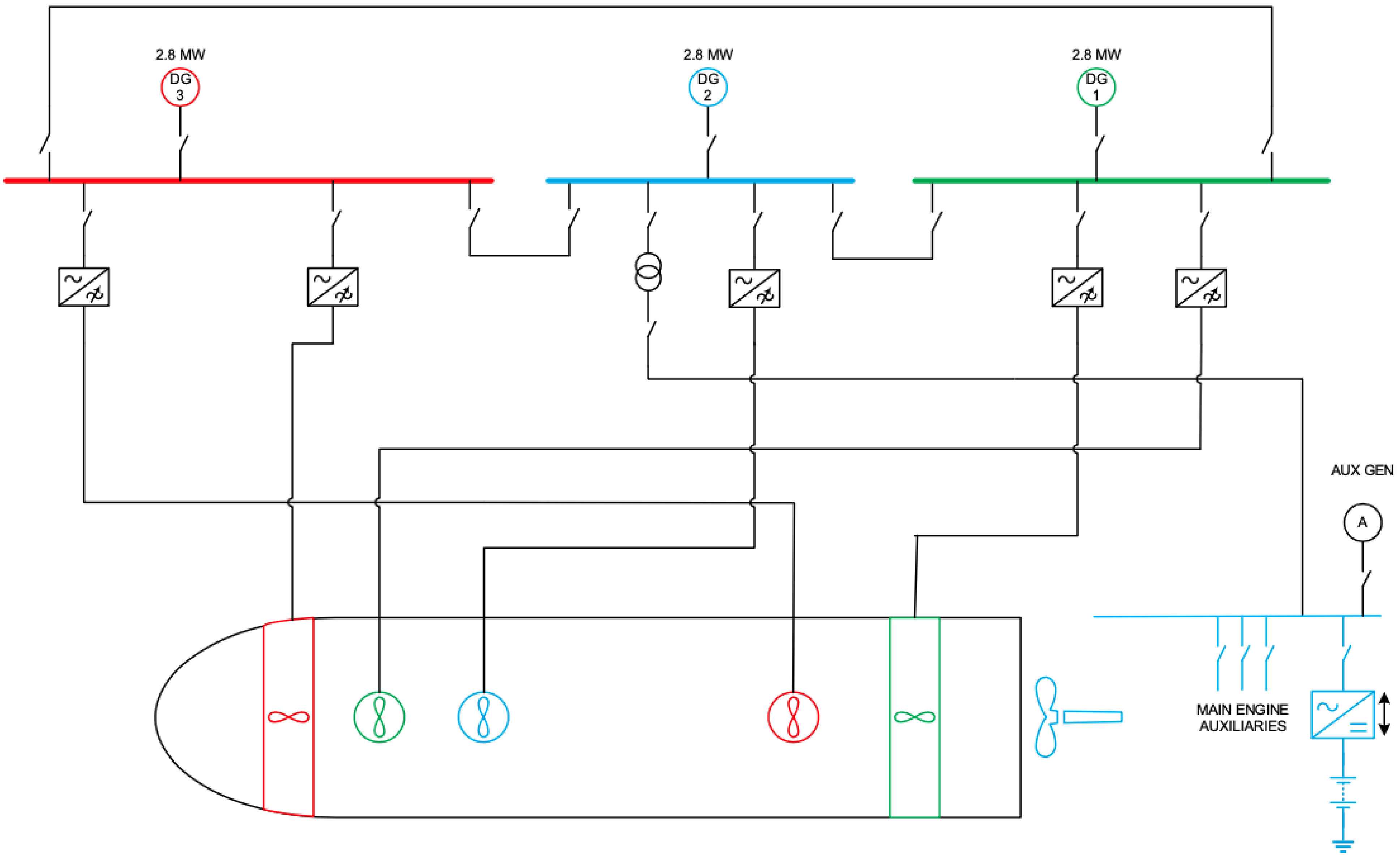


FIGURE 38 - REDUNDANCY - THREE-WAY SPLIT

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) expands on open and closed bus ties in section 13.8

13.8.1 Bustie circuit breakers should be fully independent and each should have the necessary protective functions to ensure that switchboards intended to provide redundancy can be separated.

13.8.2 In some designs only one bustie (master) has control and protection and the other bustie is a slave. Such arrangements should be avoided.

13.8.3 The above are particularly important in DP Class 3 vessels where class rules require consideration of damage by fire or flooding.

13.8.4 DP power plant can usually be operated as a common power system or as two or more independent power systems.

13.8.5 It may be possible to make a common power system fully fault tolerant in respect of single failure criteria for DP Class 2 and DP Class 3. However, in such designs fault tolerance depends on a very comprehensive range of protective functions and on many items of equipment being able to perform to capacity.

13.8.6 Operating the power plant as two or more independent power systems reduces dependence on protective functions and vulnerability to hidden failures. It does not remove all common points between redundant systems. The potential to lose one part of the system is higher but the potential to lose the complete system is reduced.

13.8.7 The security of station keeping with independent power systems still depends on redundant equipment being capable of its rated capacity and there may be greater demand for one power system to maintain position and heading in this configuration. Thus, there may also be more frequent demand for systems to operate at high load. These issues should be carefully considered when determining the critical activity mode of operation (CAMO). Designs that reduce the impact of the worst-case failure beyond that required by class improve availability to carry out the industrial mission. For example, designs that reduce impact to loss of 33% capability against 50% (See also LIFE concept).

13.8.8 It is important to understand that the integrity of station keeping ability of independent and common bus configurations depends on having all systems and equipment fully functional and available. Equipment intended to provide redundancy and fault tolerance should be periodically tested and maintained to ensure the required level of performance and to reveal hidden failures.

13.8.9 The use of distributed stored energy sources (typically batteries) can significantly reduce the criticality of protection by providing another barrier to prevent or limited the speed of loss of position giving time for blackout recovery or connection of standby redundancy.

DP Event Bulletin	ITEMS
01/23 – January 2023	Case Study – Closed Bus – Knowing the Risks
	Case Study – Open Bus Saved the Day
	Case Study – Closed Bus Ruined the Day
01/22 – April 2022	Case Study – Closed Bus Common Cause

SHORT CIRCUIT TESTING

The industry has raised concerns regarding closed bus operation.

A single failure such as a main bus fault can compromise system redundancy if the system is unable to ride through and isolate the fault or if uncoordinated tripping of circuit breakers occurs.

During short circuit conditions a severe voltage transient leading to possible uncoordinated tripping can occur causing a loss of redundant loads required to maintain vessel position during dynamic positioning operations. Additionally, an inadequate system response to an increase in load may cause generators, thrusters, or other essential DP loads to trip offline further degrading station keeping capability.

There have been several significant dynamic positioning incidents resulting in a loss of position on drill-ships that were attributed to electrical system failures associated with lack of fault tolerance and ride-through capability.

MTS has issued new guidance calling for live short circuit testing on DP vessels in order to prove that the electrical system has a fault ride-through capability while operating in a closed bus configuration such that redundancy will not be compromised in the event of a major fault.

TECHOP (D-07 - Rev1 - Jan21) A Method For Proving The Fault Ride-Through Capability Of DP Vessels With HV Power Plant January 2021

Class societies such as DNV, ABS, BV, and Lloyd's Register all require fault ride through testing prior to closed bus operations for DP3 vessels, and increasingly for DP2 vessels.

This TECHOP provides general high level guidance and is intended to be read by vessel owners, shipyards and those considering providing services in relation to fault ride through testing. However we provide the extract on short circuit testing below for you:

Test Procedure:

- *The settings on the short circuit protection of the test feeder are changed to ensure it trips after the busties open. In particular, the time delay is extended to be longer than the delay on the bustie but shorter than the generator tripping time.*
- *The simulated fault is applied by remotely closing the test circuit breaker.*
- *After a short but defined delay, the overcurrent protection opens the bustie isolating the fault to one redundant machinery group.*
- *The protection for the generators in the healthy part of the power system resets and the relays do not complete their tripping cycle.*
- *On the faulty section of the power system the fault is cleared at the test feeder. The fault is isolated and the healthy part of the plant continues without malfunction.*
- *If necessary, the test feeder timing can be extended past the tripping of the generators on the faulty side to prove they would clear the fault, but this is not strictly necessary to prove fault tolerance for DP purposes and creates uncertainty about the ride through capability of that section.*
- *The amount by which the delay is extended can be considered a margin of confidence which can be used to demonstrate that the ride through capability is not marginal.*

The power plant is normally tested in its weakest DP configuration in terms of the number of generators connected. Typically, two generators online and all thrusters and other consumers online as shown

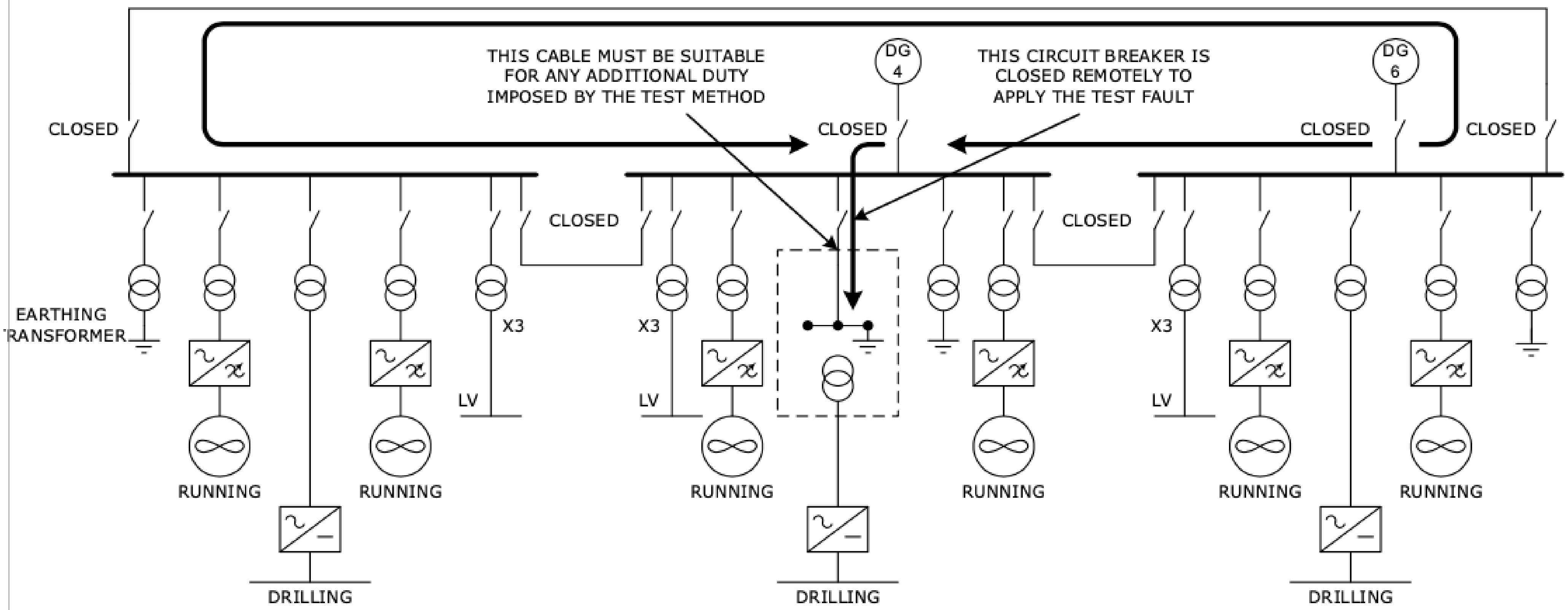


FIGURE 39 - TECHOP (D-07 - REV1 - JAN21) PROVING FAULT RIDE-THROUGH CAPABILITY OF DP VESSELS

This is necessary to ensure any malfunction or lack of voltage dip ride-through can be identified. It may not be necessary to have industrial mission equipment operating such as drilling equipment unless this is of specific interest, but distribution transformers associated with such equipment should be energised as this can influence the response of the power plant to the test (inrush current and voltage overshoot during recovery in particular). It is understood that some classification societies will require all transformers to be connected.

TECHOP (D-07) Proving Fault Ride through Capability

states that

> *10.3.1 No vessel owner should feel compelled or under pressure to carry out fault ride-through testing if they feel in any way uncomfortable or uncertain about the safety of the process. However, failure to ensure adequate fault tolerance also carries risks and it is for this reason that MTS guidance promotes the concept of CAM and TAM and the 'build to test' philosophy.*

And that

> *The test methods described in this TECHOP are not suitable for all types of DP power plant. There will be a need to develop suitable methods, specific to the power plant design, to demonstrate fault ride through capability if it is intended to conduct critical DP operations with their diesel electric power plants configured as a common power system.*

OneStep Power have developed testing tools to provide dynamically positioned vessels with assurance of the reliability of their power systems. The key technology, the Generator Voltage Response Tester (GVRT) was created to mimic the voltage responses of a short circuit - a voltage dip and a transient over-voltage. The goal of the GVRT was to provide a safe and realistic alternative to "short circuit" tests.

> *"For closed systems, in particular, fault ride through testing supplemented by validated computer simulation will play a crucial role as the industry begins to increase its use of closed bus configuration in light of requirements for lower emissions and fuel consumption,"* Steven Mearns Cargill Technical Authority for Dynamic Positioning, DNV GL

The GVRT and associated technologies such as ZeroDip provide a safe test:

- No changes to protection settings
- No personnel in high-risk areas during testing
- No damage to equipment
- Repeatable
- Invisible to the ship's system

The difference between **Short Circuit and GVRT Testing?**

Considerations	Short Circuit	GVRT
Current Level	High Current	**No Current spike**
Equipment Impact	Reduces equipment life	**100% safe** for all equipment
System	Tests single fault path	**Only test** to verify entire system
Time	Time intensive	Takes **less time**
Summary	Destructive testing	**Proven Safe** Technology

FIGURE 40 - ONE STEP GVRT SOLUTION

OneStep Power state:

Bolted short circuits, while possible on high voltage switchgear, are not viable for low voltage (690V or 480V) systems and may not be suitable for hybrid vessels, or vessels which were built prior to the "Built to test" guidance which became prevalent in 2017. This is primarily due to the high currents encountered during short circuit testing. These current spikes are not present using OneStep Power's technologies, presenting a safer solution for equipment throughout the power network.

Short circuits are not an easily repeatable test - should equipment not ride through the voltage transients, the test cannot be easily performed again. Further, a short circuit test can only validate one fault path. Without performing the test multiple times, it's impossible to use a short circuit test to validate the outcome of all possible fault locations. Conversely, OneStep Power's testing presents the fault to the full system, demonstrating the fault ride through capability of the integrated power system - from thrusters to DP controllers to lights.

Given the right vessel access, GVRTs takes only a day to install, and generally a day to test is all that is required. We test the system multiple times and can test a range of configurations to match all DP FMEA requirements.

DP Event Bulletin	ITEMS
IMCA Safety Flash 11/13 June 2013	USCG Homeport Marine Safety Alert: Recent failures of dynamic positioning (DP) systems on MODUs

POWER LIMIT – AS PER IMO 1580

'Power limit' refers to the maximum amount of power that can be consumed on a vessel. This limit is set to prevent overloading of the power generation and distribution systems.

IMO 3.2 IMO MSC/Circular 1580 does not specially mention power limits but rather states the following conditions that a power plant on board equipment class 1, 2 and 3 vessels must be able to meet.

3.2.1 The power system should have an adequate response time to changes in power demand.

3.2.2 For equipment class 1, the power system need not be redundant.

3.2.3 For equipment class 2, the power system should be divisible into two or more systems so that, in the event of failure of one sub-system, at least one other system will remain in operation and provide sufficient power for station keeping. The power system(s) may be run as one system during operation but should be arranged by bus-tie breaker(s) to separate the systems automatically upon failures which could be transferred from one system to another, including, but not limited to, overloading and short circuits.

3.2.4 For equipment class 3, the power system should be divisible into two or more systems so that, in the event of failure of one system, at least one other system will remain in operation and provide sufficient power for station keeping. The divided power system should be located in different spaces separated by A-60 class divisions. Where the power systems are located below the operational waterline, the separation should also be watertight. Bus-tie breakers should be open during equipment class 3 operations unless equivalent integrity of power operation can be accepted according to paragraph 3.1.4.

3.2.5 For equipment classes 2 and 3, the power available for position keeping should be sufficient to maintain the vessel in position after worst-case failure according to paragraph 2.2.

3.2.6 For equipment classes 2 and 3, at least one automatic power management system (PMS) should be provided and should have redundancy according to the equipment class and a blackout prevention function.

3.2.7 Alternative energy storage (e.g. batteries and fly-wheels) may be used as sources of power to thrusters as long as all relevant redundancy, independency and separation requirements for the relevant notation are complied with. For equipment classes 2 and 3, the available energy from such sources may be included in the consequence analysis function required in paragraph 3.4.2.4 when reliable energy measurements can be provided for the calculations.

3.2.8 Sudden load changes resulting from single faults or equipment failures should not create a blackout.

IMO MSC/Circular 1580 states that:

3.2.7 Alternative energy storage (e.g. batteries and fly-wheels) may be used as sources of power to thrusters as long as all relevant redundancy, independency and separation requirements for the relevant notation are complied with. For equipment classes 2 and 3, the available energy from such sources may be included in the consequence analysis function required in paragraph 3.4.2.4 when reliable energy measurements can be provided for the calculations.

The term 'Hybrid Power' is used to describe a power system with a mix of energy sources. In the case of DP vessels with hybrid power, the term is most commonly used to indicate that the electrical power generation system can be powered from a combination of diesel generators and power electronic convertors supplied from stored energy sources such as batteries. The term can however be applied to other combinations of energy sources. Classification society rules guide the way in which hybrid power can contribute to redundancy based on the time to terminate the DP operation. The 'time-to-terminate' is a key factor in dimensioning the energy storage system. Emphasis is placed on clear and unambiguous indication to the operator that the plant is using stored energy and the remaining time available on stored energy. This is an area of focus for some classification societies.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) suggests that a hybrid system can provide time when it is needed most. This time can be the difference between a failure cascading to a catastrophic failure and a favourable recovery from a critical failure.

Energy Storage in the form of batteries or other devices may be applied at different points in the power systems.

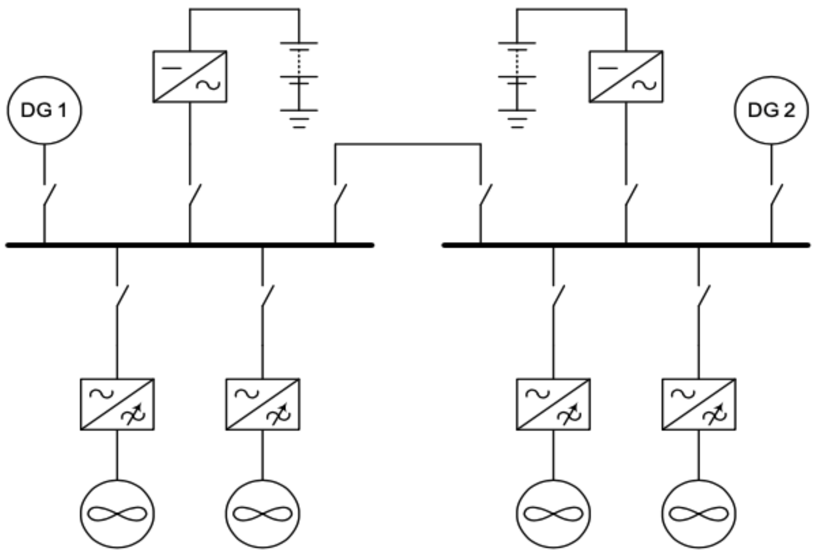


FIGURE 41 – BATERY HYBRID (PART 1) - MTS DP VESSEL DESIGN PHILOSOPHY GUIDELINES (REV2 - APR21)

Although it is possible to create acceptable designs using a variety of design concepts there are advantages in providing the thrusters with their own dedicated stored energy systems.

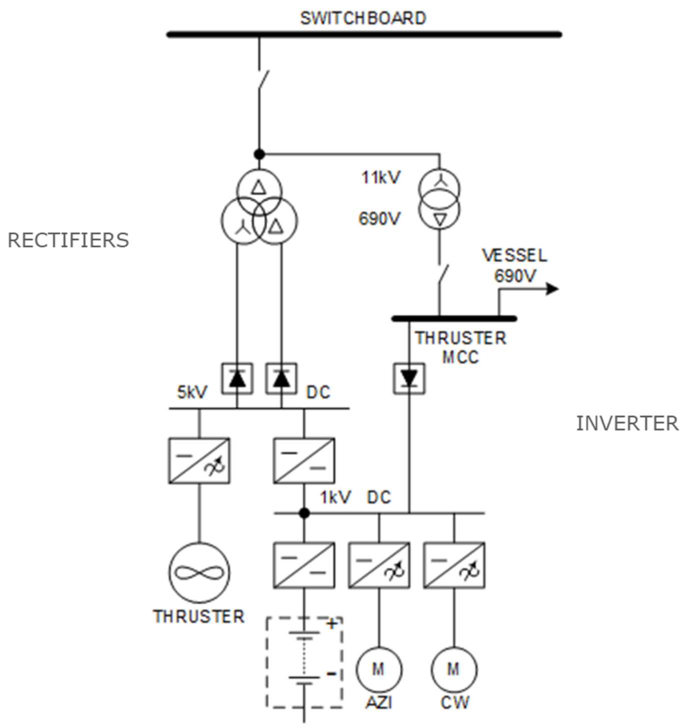


FIGURE 42 - – BATERY HYBRID (PART 2) - MTS DP VESSEL DESIGN PHILOSOPHY GUIDELINES (REV2 - APR21)

This concept provides an additional layer of defence against loss of power to a thruster function through built in energy storage supplied directly to the thruster prime mover and critical auxiliaries.

In the event of a partial failure (complete bus) or complete failure of the infrastructure required to support and provide power to the thrusters, the thruster hybrid power system is able to be isolate the thruster from its main power supply and continues to provide power to the thruster prime mover and critical auxiliaries. This makes the thruster completely autonomous for a finite amount of time. The amount of time is dependent on the power required and amount of energy storage that is in the system. The duration of this autonomous capacity and therefore the amount of energy storage required is determined by the operating profile of the asset and the time required to safely suspend operations plus a design safety margin.

Adding energy storage (typically batteries) directly at the thrusters can provide propulsion capability or ride through during a power plant blackout even if the power distribution system is damaged or otherwise unavailable. This should be considered as an alternative or supplement to adding electronic generators and energy storage to the main bus.

Many hybrid power schemes treat the stored energy and conversion systems as ‘static’ or ‘solid-state’ generators connected to the main power distribution system (or sometimes on the LV power distribution). This may be the easiest approach for retrofits and allows the energy to be distributed to anywhere it is needed (but it may also be more difficult to ensure it goes where it is most needed). Other designs provide local energy storage at the thrusters and drawworks.

MTS DP Vessel Design Philosophy Guidelines offer the following advantages of this arrangement:

- *The power can be reserved for use by critical consumers and not depleted by others.*
- *When the energy storage and conversion equipment is located downstream of the rectifiers that feed those consumers, it cannot feed a distribution side fault and thus there is no change in the fault characteristics of the power plant. Coordination studies and short circuit test results remain valid. This may be beneficial for upgrades and conversions.*
- *The distributed nature of the battery installation means the concentration of flammable or explosive materials in any one space is reduced.*
- *The thrusters do not stop during blackout and blackout recovery (but may operate at reduced power). This reduces the criticality of the dependence on correct functioning of protective functions that are intended to*

prevent blackout. All such protective functions are potential hidden failures, so this arrangement provides another barrier to immediate loss of position even if the protection systems have failed to deal with the cause of the blackout correctly.

- *If properly designed for operation in emergency conditions, hybrid power offers the possibility of DP MODUs retaining some propulsion capability with the engines shutdown which may be beneficial in the case of a hydrocarbon gas release.*

Connecting the batteries at the thrusters rather than to the busbars will require batteries to be installed at more locations with consequential infrastructure requirements.

However, there are several design and operational issues to be considered when implementing a hybrid power solution and the MTS document goes on to say:

- ***Battery safety**: There are a variety of battery chemistries. Some are associated with greater fire and toxicity risk than others. Batteries are a potential fire risk but are also at risk from fire. It is for these reasons that there are restrictions on battery location and requirements to protect batteries from fire. Cooling, ventilation and fire suppression measures are other facilities to be considered.* (See below)

- ***Time to terminate**: Propulsion capability on battery power and time taken to terminate the DP operation safely influences whether the stored energy system can count towards redundancy and post failure DP capability. Part of the work in dimensioning a hybrid power system is to identify the time to terminate the intended DP operation and estimate the power and energy required from the batteries. If the batteries can be dimensioned to provide power for long enough to safely terminate the work in progress, then they can be considered to contribute to redundancy and post failure DP capability.*

- ***Timeline**: When dimensioning the battery banks the following should be take into consideration:*

• The classifications societies generally do not validate that the timeline provided to them is sufficient to allow the stated operation to be terminated, only that the installed hybrid system has the capacity to provide the stated endurance in the defined conditions.

• Means and time to detect that propulsion is being supplied from batteries (time on DP is now limited by battery endurance).

• Time to take action and communicate the need to terminate the operation.

• Time to terminate the operation.

• The possibility that the environment may increase during the time it takes to terminate the operation.

• The propulsion capability required in the intact and post worst case failure conditions.

• If the batteries cannot be dimensioned to achieve this requirement, they can still be used for peak shaving provided the 'spinning reserve' required for DP redundancy is supplied by the diesel generators.

Note: Provided the batteries are dimensioned to allow the work in progress to be terminated it is possible to rely on the connection of standby machinery and blackout recovery to prevent further position loss position and potentially prevent having to terminate the operation. This is based on the time on DP available from the batteries being sufficient to wait for a successful standby start before taking the decision to commence termination of the operation (in case the standby start was not successful).

BMS – Batteries require their own dedicated management systems. Battery banks are made of modules which are, in turn, constructed from many such smaller cells. Battery Management Systems (BMS) must perform several functions including:

• Protecting the batteries from over charging. Lithium cells are particularly sensitive to overcharging and failing to manage this aspect correctly has severe consequences including thermal run-away, off gassing of flammables and explosion.

• Balancing the charge in each module, and in some designs, balancing the energy in each cell.

• The BMS will typically monitor the 'state of charge' and 'state of health' of the battery bank. Battery banks are typically dimensioned to allow for decrease in capacity with age and duty cycle.

BATTERY SAFETY

Battery safety is a subject in its own right and a considerable part of the verification and validation effort is focused on ensuring the battery banks do not significantly increase the risk of fire and explosion.

However, it is worth noting that there are many other fire and explosion risks associated with diesel electric power plant that are currently accepted. The requirements for ventilation and fixed firefighting are influenced by the amount of gas that can be evolved from a battery bank. Restrictions of location within the vessel's hull also apply in recognition of the increased fire risk to the batteries from other sources of ignition. MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) consider fire and explosion risk in two ways*:*

> *• Internal - The risk of off-gassing from within the battery bank – The amount of gas evolved can be reduced if the design limits the effects of internal faults to a single cell. A cell may short circuit, It the adjacent cells do not fail because of this short circuit and the heat from the faulty cell does not drive the adjacent cells into thermal run- away then it can generally be accepted that the contents of one cell is defined as the total amount of explosive / toxic gas that can be released. The BMS must also prevent the whole battery bank being exposed to an over voltage / overcharging.*
>
> *• External – It has to be assumed that the entire battery banks could be subject to thermal run-away and off-gassing if it is consumed by an external fire source. Verification and validation activities attempt to assess the likelihood of this event based on the fire risks in the compartment in which the battery bank is located. Firefighting systems may contribute to a lowering of the risk. Flooding or water ingress may also be a credible threat.*

DP Event Bulletin	ITEMS
Safety Flash 09/22 – April 2022	USB power bank (Lithium battery) fire

BATTERY MANAGEMENT SYSTEM

Batteries require their own dedicated management systems. Battery banks are made of modules which are, in turn, constructed from many such smaller cells. Battery Management Systems (BMS) must perform several functions including:

- Protecting the batteries from over charging. Lithium cells are particularly sensitive to overcharging and failing to manage this aspect correctly has severe consequences including thermal run-away, off gassing of flammables and explosion.
- Balancing the charge in each module, and in some designs, balancing the energy in each cell.
- The BMS will typically monitor the 'state of charge' and 'state of health' of the battery bank. Battery banks are typically dimensioned to allow for decrease in capacity with age and duty cycle.

> *Note: Classification society rules may influence the way in which the capacity and power delivery of stored energy systems is integrated into power available calculations. A fuel gauge or **'time on batteries' at present thrust levels may be required for display to the DPO** and for use by the consequence analyser.* MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21)

UPS - FOLLOWING REDUNDANCY, THE REQUIREMENTS OF OPERATION

The purpose of a UPS in a DP system is to provide: -

- Stable, clean power.
- Continuity of power during main power system outage.
- Power system transient ride through capabilities.

IMO MSC/Circular 1580 states that a power system means all components and systems necessary to supply the DP system with power

including uninterruptible power supplies (UPS).

and that a:

dedicated UPS should be provided for each DP control system.

That is a minimum of

- one UPS for equipment class 1,
- two UPSs for equipment class 2
- and three UPSs for equipment class 3

to ensure that any power failure will not affect more than one computer system and its associated components.

Position reference systems and sensors should be distributed on the UPSs in the same manner as the control systems they serve, so that any power failure will not cause loss of position keeping ability.

An alarm should be initiated in case of loss of charge power or if the unit is in 'Bypass' mode.

UPS battery capacity should provide a minimum of 30 minutes operation following a main supply failure. For equipment classes 2 and 3, the charge power for the UPSs supplying the main control system should originate from different power systems.

IMO MSC/Circular 1580 also states that the power supply for the independent joystick system (IJS)

is to be independent of the DP control system UPSs.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) suggests that the design of UPS systems, their power sources and distribution should:

- *Accomplish robustness.*
- *Follow the Redundancy Concept.*
- *Not introduce additional vulnerabilities.*

The design of a UPS system should follow either a centralized topology or distributed topology. Centralized topology lends itself to a robust system but introduces commonality while a distributed system potentially could be less robust and minimizes commonality. Commonality potentially increases the amount of equipment lost as a consequence of failure.

The MTS guidelines suggest that the distribution of UPS power from centralized sources may be particularly challenging in DP Class 3 designs but some compromise between a large number of small UPSs and fewer larger UPSs (supporting the overall split in the redundancy concept) should be achievable.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) states that

> *The redundancy concept should not be dependent on battery endurance. UPSs should be provided in a manner which supports the WCFDI and matches the divisions in the redundancy concept. (Minimum two UPSs for DP Class 2 two-way split and minimum three UPSs for DP Class 3 two-way split plus backup DP control system).*
>
> *Note: The temptation to solely comply with the minimum class requirements and not align the UPS installation and distribution with the divisions in the redundancy concept may result in undesired and unwarranted cross connections between redundancy groups which could negatively impact achievable post failure capability. This is specifically the case where the number of redundancy groups exceeds two.*

FAILURE OF A UPS AND MITIGATION

Failure of a UPS output should not lead to failure effects exceeding the worst case failure design intent. Input power supplies for DP related UPS's should be split in line with the redundancy concept.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) states that

> *Where a group of UPSs share a common input power supply, loss of that power supply (switchboard) should not lead to failure effects exceeding the worst case failure design intent when all UPS batteries in that group are exhausted. Classification society requirements for UPS battery endurance are typically 30 minutes. Consideration should be given to extending the endurance if required by the industrial mission. Where UPS's are provided with a normal and back up supply, the normal power supply should be from the appropriate part of the main power systems. The backup supply should be from the emergency switchboard when this does not compromise the redundancy concept.*

The emergency switchboard may be usefully employed as a backup supply to UPSs to allow batteries to be charged when the main power system is not available. There should be means to isolate potential fault propagation pathways if it compromised the redundancy concept. Automatic and manual transfer to the backup supply is possible.

ALARMS

There should be a remote indication that the UPS is connected to its normal supply.

UPSs should be provided with comprehensive alarm and monitoring facilities. As a minimum there should be alarms to indicate.

- *UPS on batteries.*
- *UPS in bypass.*
- *Battery disconnected.*
- *Mains power present.*

AUXILIARY SYSTEMS

Auxiliaries such as cooling water pumps and fans should be powered from same source as drive main power. Control power should be provided from a UPS. The main input to the UPS should be from the thruster auxiliary system power supply. A backup power supply to the UPS input should be arranged from the emergency switchboard.

Power supplies for field stations should be from UPS distributions which are arranged in a manner that supports independence and the redundancy concept.

FAULT PROPAGATION OUT OF COMPARTMENTS

UPS output should not cross the boundaries between redundant equipment groups. This is particularly important in DP Class 3 designs.

IMCA M103states that.

> *Fault propagation out of compartments by way of cables and pipework can occur. Control power supplies from UPSs are particularly vulnerable and often cross the boundaries between redundant groups. UPSs should be designed to withstand a fault current and continue to operate selectively or without an unacceptable voltage dip.*

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Event Bulletin 04/17 October 2017	Check of the UPS led to loss of power – DP incident

Whilst this section has focussed on inverter type AC output UPS units, the same can be applied to Battery systems (24V, 110V etc) supporting navigational equipment, PMS systems (Engine control, governors and AVRs), switchboard systems etc)

DC GRIDS

In an AC-grid system maintaining power stability requires the monitoring and controlling of both voltage and frequency. Primarily to balance the load and VAR between the engines. The disadvantage is that the engines must run at a fixed speed even when at low load. The advantage is the simplicity of switchgear, protection systems and cheap fixed speed motors and starters.

A DC-grid system does not face reactive power interactions making system control solely based on power/voltage regulation. As a result, the DC-grid system has an advantage in maintaining power stability over the AC-grid. This means that we can run the engines at a more efficient speed (i.e. generally slower than synchronous speed)

The downside of DC is fault interruption as there is no 'zero crossing' that you get with AC. However, the industry is coming up with novel solutions such as solid state switches etc.

Generator connection in the DC-grid system is simpler. In an AC-grid synchronizing more than two generators requires considering voltage, frequency, and phase angle. In contrast, the DC-grid system only requires monitoring voltage for successful generator connection.

DC power systems are becoming more common. In these systems the output of AC generators is rectified to DC and fed to a DC distribution system and advantages include:

Fuel efficiency: When diesel-electric generators run at constant rpm fuel efficiency is compromised. By distributing electricity in DC it is no longer required to maintain a fixed electrical frequency. Consequently, the engines can run at variable speed and therefore at the best possible operating point to achieve the best fuel efficiency along the full power range.

Redundancy protection: Each power source and consumer on the DC grid is an AC or DC "island" and the only connection between them is the DC bus. This yields two advantages:

- Each power source and consumer can be controlled and optimized independently.
- Complex interactions that can arise between units that share an AC connection will never occur. Consumers fed by the DC grid are designed not to interact even under fault conditions.

Energy storage: Diesel engines are slow to handle large, quick load changes. Using batteries to provide power for a short time can improve the vessel's control capabilities Energy storage can also be used to absorb rapid power fluctuations seen by the diesel engines, thereby improving their fuel efficiency.

However, IMCA M103states that *such systems do require more power conversion equipment.*

The main switchboards may be operated as isolated power systems, as a linear bus or a closed ring. The arrangement of DC for control power may vary in design.

However, IMCA M103states that *Isolated power systems are preferred although cross connected systems may be used*.

There could be a large number of potential fault propagation paths associated with power, protection and control lines crossing the boundaries between redundant groups and this must be analysed in the FMEA.

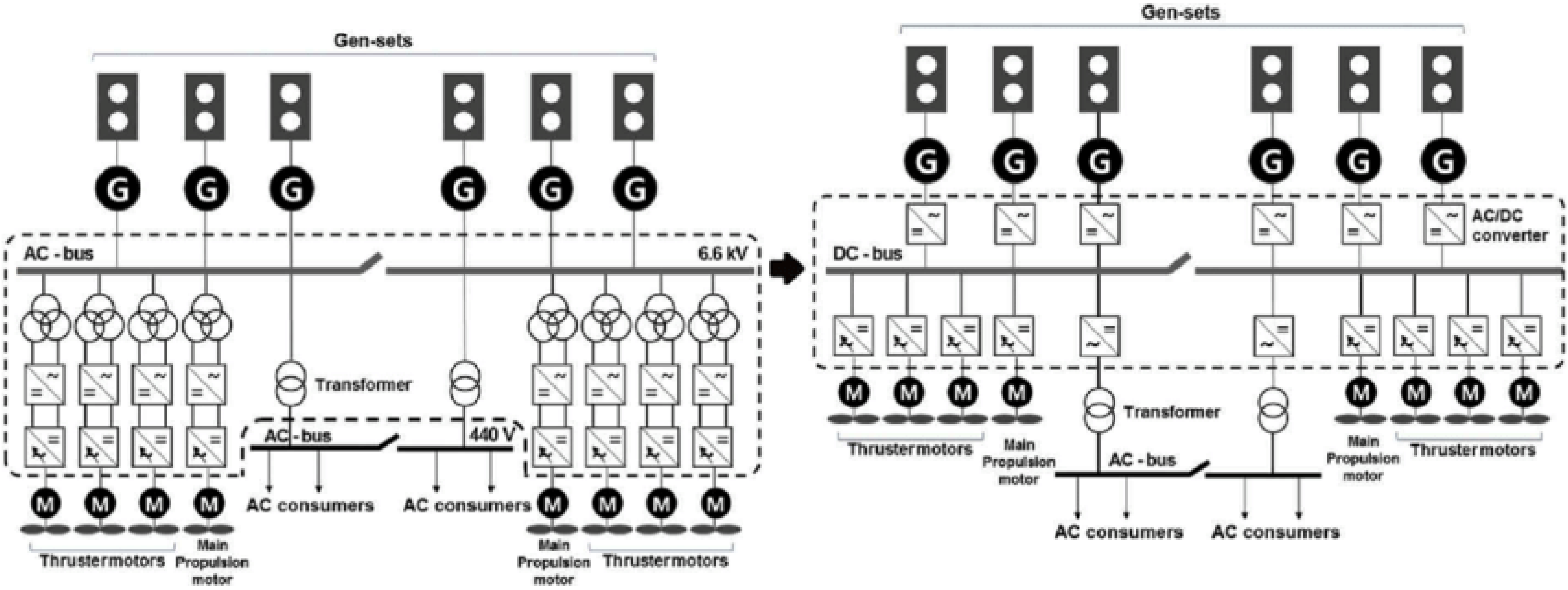


FIGURE 43 - Comparison Between the Conventional ACV-Grid and Proposed DC-Grid of a Pipelayer Ship (KIM 2017; Siemens 2017, 73-80)

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Bulletin 03/19 September 2019	DP3 drillship switchboard blacked out – DP undesired event
DP Event Bulletin 01/23 – January 2023	Case Study – Closed Bus – Knowing the Risks
DP Event Bulletin 03/21 – August 2021	DP Emergency Drill Scenario RECOVERY FROM FULL BLACKOUT
IMCA DP Station Keeping Bulletin 03/18 August 2018	Case study – Load sharing imbalance caused loss of position
IMCA Safety Flash 07/02 July 2002	Power management system dynamic positioning (DP) incident

TECHNICAL AND OPERATIONAL GUIDANCE (TECHOP) TECHOP (G-02 - Rev1 - Jan21) POWER PLANT COMMON CAUSE FAILURES JANUARY 2021

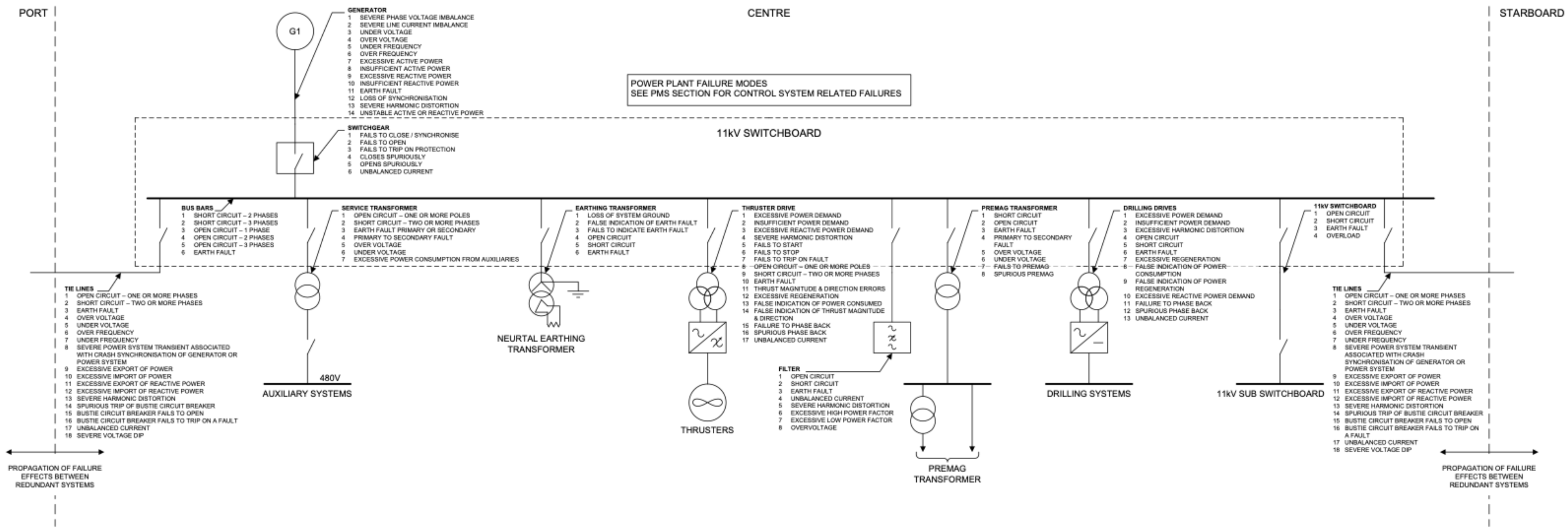


FIGURE 44 - TYPICAL HV SYSTEM & FAILURE MODES

The diagram above is accessible from the TechOp link above and represents the typical HV power generation and distribution systems components and their failure modes.

- There are a wide variety of common cause failures that can affect the operation of DP related systems in any power plant configuration.
- A DP power plant operated as a common power system closed bus) is vulnerable to a range of failure modes not addressed by traditional protection schemes.

Thrusters and Thruster control systems
Thrusters - Overview
Thruster types - Overview, advantage, disadvantage
Thruster allocation / Modes of operation - e.g. bias and considerations therein
Thruster control system - the basics including EM stops and emergency/Backup controls
Thrusters - Failure modes and their effects on operations
Lessons learnt from DP Events
New developments in the last 5 years

Thrusters play a critical role in the operation of an DP vessel.

DP vessels typically have multiple thrusters installed around the hull, including azimuth thrusters that can rotate 360 degrees and tunnel thrusters that are mounted in the bow or stern of the vessel. These thrusters work together with a computer control system to make small adjustments to the vessel's heading and position in real-time.

For DP the primary function of the thrusters is to provide the necessary thrust to counteract the environmental forces acting on the vessel and keep it in its desired heading and / or position.

In many vessels the aft propellers are also required for transit, towing, etc. and may have a rating disproportionate to that required for DP purposes.

The positioning of the thrusters should be such that effective thrust can be generated in surge, sway and yaw in both intact and post worst case failure conditions. Effective thrust capability is dependent on the lever arms. This should be taken into consideration during the design phase. Location of thrusters should be optimized and is dependent on the hull geometry.

For a monohull, the most onerous criteria for the assessment of the DP capability of a vessel are its performance when exposed to environmental forces from the beam direction. A vessel which excels in this condition typically performs well in any other situation. Care should be exercised when assessing DP capability of a vessel where a portion of the thrust is required to carry out the industrial mission (for example thrust to overcome bottom tension on a S-Lay pipe lay vessel.

For effective counter forces against wind, the size (capability) of the thrusters should be approximately proportional to the windage area at the area of installation. In other words, a vessel with a high superstructure forward requires the installation of adequately sized thrusters forward. Failure to follow this basic design philosophy introduces the potential to lose station in conditions where the wind velocity and direction is shifting rapidly.

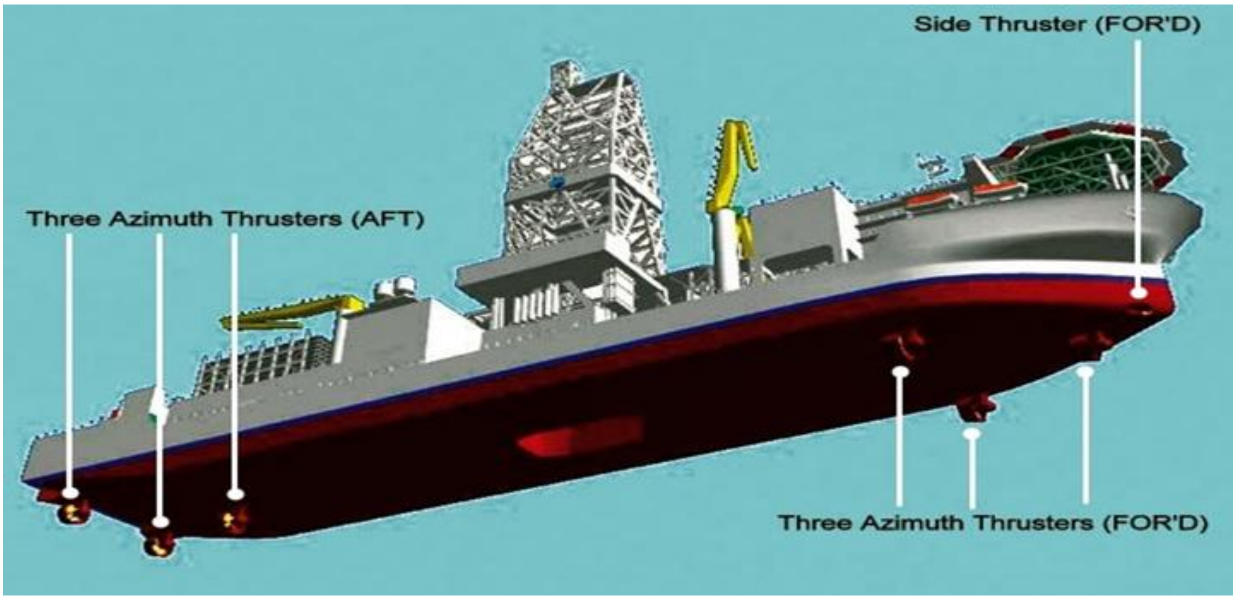


FIGURE 45 - TYPICAL DRILLSHIP THRUSTER LOCATIONS

The number of thrusters should be determined by:

1. The ability to develop forces in surge, sway and yaw post worst case failure.
2. Classification society requirements for redundancy post worst case failure.
3. The desired post failure DP capability for the industrial mission.
4. Maintenance considerations - maintaining redundancy for both intact and post worst case failure conditions when a thruster is taken out of service for IRM. For example, a scenario where a vessel with a four-thruster configuration where power distribution is such that two of them come off each switchboard. When one thruster is required to be taken out of service - post worst case failure capability is reduced to one thruster and vessel may not be able to maintain station.

THRUSTER TYPES OVERVIEW

There are three types of thruster:

- Azimuthing propulsors.
- Fixed direction propulsors.
- Hybrid concepts utilizing a combination of azimuth thrusters and fixed-direction thrusters.

ADVANTAGE, DISADVANTAGE

Propulsors with fixed direction of thrust			
TYPE	**APPLICATION**	ADVANTAGES	**DISADVANTAGES**
In-Line Conventional propulsion systems	Used widely for transit as well as station keeping (providing thrust in longitudinal direction) on ship shaped DP vessels (OSV's, diving support vessels, pipe-laying vessels, older generation of drill vessels)	Simple, reliable, robust and proven system. Very low maintenance, highly efficient for DP when equipped with ducted propellers	Requires reverse gear or CP propeller to change direction from AHEAD to ASTERN. Additional thrusters needed for transverse thrust forward and aft. Efficiency reduced in reverse operations
Transverse Tunnel Thrusters	nstalled in the bow and/or stern of vessels to provide transverse thrust and forces for yaw manoeuvres	Simple installation inside a transverse tunnel in the hull. Well protected; hydrodynamically smooth uniform operation; long life	Mediocre performance (depending on length of the tunnel, tunnel exit/entrance configuration). For fixed pitch propellers, reversing of the sense of rotation is required to change the direction thrust. No access for maintenance. Removal/instal lation requires drydocking in most cases; may lose thrust during heavy motions of the
Ducted transverse thrusters	nstalled below the hull, forward and aft to provide transverse thrust; mostly installed in retractable containers. Bi directional ducts and propellers generate equal amounts of thrust in both transverse directions. Many successful installations on first generation DP drill vessels	High performance in both directions. Simple and robust design. Access for maintenance after retracting the assembly	For fixed pitch propellers, reversing of the sense of rotation is required to change the direction of the thrust.

Propulsors with fixed direction of thrust			
TYPE			
Azimuth thrusters including Azipods	Most popular thrusters applied for transit as well as station keeping for DP MODUs (Mono hull and column stabilized) Typically installed under the bottom of the hull thus increasing the draft of the vessel, Smaller ship shaped DP vessel (OSV's etc.) uses azimuth thrusters installed in the skeg of the vessel (above the base line). Installation forward requires retractable azimuth thrusters to minimize draft during transit	Reliable proven designs, High performance. Bottom mounted thrusters are accessible for maintenance after underwater removal, No drydocking required for maintenance. Containerized azimuth thrusters:- This thruster is installed in a watertight container which encloses the drive motor and the auxiliary systems. The entire container is retractable to a position above the waterline at which servicing the thruster is feasible. This is the optimum installation for DP application if achievable.	Underwater installation and removal complicated and time consuming. Requires support vessels in many cases. Retractable azimuth thrusters (without containers) are mechanically complex, expensive, require a high degree of maintenance. Access typically only during dry-docking. Custom dock preparations necessary
Voith Schneider propellers (VSP)	A very special type of propulsor applicable for DP operations. It is a cycloidal propeller operating on a vertical axis.	The VSP is an ideal propulsor for DP combining the propeller characteristic of a controllable pitch propeller combined with control of the direction of thrust through 360 degrees. Allows step less control of thrust in magnitude and direction. Can be supplied with active anti-roll system. (This might introduce commonality and use on	The mechanical complexity, high costs, and maintenance of a large diameter seal limit the application to low draft vessels and usually for specialized applications.

THRUSTER ALLOCATION - EG BIAS AND CONSIDERATIONS THEREIN

THRUSTER ALLOCATION

Thruster allocation refers to the process of determining which thrusters to use and how much power to apply to each thruster to achieve a desired position or heading for a dynamic positioning (DP) vessel.

On a DP vessel, the thruster allocation system is a fundamental part of the DP and is responsible for distributing the required force on the vessel to the thrust generated by each thruster in a manner that maximizes the vessel's manoeuvrability while minimizing the fuel consumption. The thruster allocation system takes into account various factors such as vessel speed, heading, wind, current, and wave conditions to determine the most efficient thruster configuration.

The thruster allocation system is typically integrated with the vessel's DP control system, which constantly monitors the vessel's position and heading and makes adjustments as necessary. The thruster allocation system also takes into account the limits of the thrusters, such as maximum thrust, minimum thrust, and maximum speed, to ensure that the thrusters are used within their design parameters.

Thruster allocation is an important aspect of DP vessel operation as it allows the vessel to maintain its position accurately, even in challenging weather conditions, while minimizing the use of fuel and reducing the risk of damage to the thrusters or other components of the vessel.

THRUSTER BIAS

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) states that *DP Control system thruster allocation logic on vessels with azimuthing thrusters often have a 'thruster bias' feature. This feature allows thrusters to be run against each other.*

The "thruster bias" feature or 'bias mode' of a DP control system refers to a function that allows the operator to group thrusters so that they generally act against each other to provide the thrust required. The thruster bias feature is generally used when the environmental forces are low. Typically, azimuth thrusters are directed towards one another and run at an equal but minimal thrust producing a net zero force. If thrust is required in one direction one thruster increases, and hence the vessel is pushed that way, to stop the motion the other thruster increases and the first goes back to minimal. This avoids having to turn the thrusters through 180 degrees each time thrust is required in the opposite direction.

Note when the environment increases then all the thrusters will 'push' into the environment and if the push too hard and hence the vessel position is 'up wind' then by reducing the thrust the environment bring the vessel back rather than rotating thrusters 180 degrees.

With the thruster bias feature, the operator can adjust the amount of thrust generated by each thruster, either individually or as a group, to achieve the desired control for the vessel.

The thruster bias feature can help to improve the control of the DP system in light environments by allowing the DP system to minimize the azimuth rotation of the thrusters. It can also help to reduce the risk of damage to the thrusters and other components of the vessel by preventing overuse by the DP constantly rotating all the thrusters.

To use the thruster bias feature effectively, it is important for the operator to have a good understanding of the vessel's operating conditions and the performance characteristics of the thrusters. The operator should also be aware of the limitations of the thrusters and the DP control system and should use the thruster bias feature within these constraints to ensure the safe and efficient operation of the vessel.

The bias system will have limits that can be adjusted by the DPO, so for instance if the thrusters in bias have a minimum power setting of 5% but a maximum of 25%. As the force required grows to get the required thrust one may be at 20% while the other is still at 5% so the net result is 15% (but using 25% total power for that group) if the force required was to be the equivalent of 40% , then if they were still in bias one would be 45% and the other 5% , but the limit is set at 25% so in fact 'bias' is overridden and both thrusters provide 20% in the same direction.

In some DP systems once bias is overridden the DPO must initiate it again if conditions allow, in other systems it is overridden while the condition exists but then will revert to bias automatically if the thrust demand falls within the limits once again.

In reality, the thrusters may not directly oppose one another and there is another factor which overrides 'bias' and that is the 'turn factor'.

Finally, if two thrusters are part of a bias group and one trips, then the other reverts to free mode.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) offers the following comments on thruster bias and it's use.

1. In light conditions, Thruster bias is used to prevent excessive azimuthing causing undue wear and tear.

2. Thruster bias is sometimes used to provide a base load intended to protect the power plant from blackout. The failure scenario involves a diesel generator governor taking the engine to full load and the remaining diesels tripping on reverse power.

3. This however is not without potential problems as in an incident where a governor failed, and the base load of the bias was sufficient to avoid a black out. The operator however saw the faulty generator at full load and manually reduced the bias to try and lessen its load, this then tripped the healthy remaining generators on reverse power and the unhealthy one on overload which blacked the vessel out.

4. This method of protection also requires that the healthy generators are able to accept the step load which occurs when the faulty generator trips.

5. Thruster bias can be shed manually or automatically. Shedding bias automatically can cause a position excursion to the surprise of the operator. Position loss can also occur in the case of systems that only have manual selection / de-selection of bias. Forgetting to remove the bias as the weather increases has resulted in loss of position incidents.

6. Some DP control systems shed thruster bias automatically on:

a. Thruster alarm conditions.

b. Detection of insufficient thrust.

c. Insufficient power or insufficient thrust.

7. Designs that shed bias on insufficient power should be considered for vessels with critical power consumers required by the industrial mission. For example, DP drilling vessels with active heave compensation.

THRUSTER BARRED ZONES

A "barred zone" or “Forbidden zone” with regards to thrusters on a dynamic positioning (DP) vessel is a restricted area (or angle) within which a thruster should not be used. The barred zone is typically defined by the manufacturer or the DP system provider and is based on the design of the vessel to avoid wash being directed into another thruster, or towards a moonpool, acoustic pole, taut wire, ROV LARS etc.

The purpose of the barred zone is to prevent the thrusters from being used in a way that could cause damage or compromise the performance of other equipment.

The barred zone is an important consideration when operating a DP vessel, as it can affect the manoeuvrability and efficiency of the vessel.

To ensure that the thrusters are not used within their barred zones, the DP control system is typically programmed with the restricted areas for each thruster. The DP control system will then prevent the thrusters from being used in these areas, and will automatically adjust the distribution of thrust among the thrusters to ensure that the vessel remains in its desired position and heading while avoiding the barred zones.

Often it is also possible for the DPOs to add further barred zones on a temporary basis depending on the industrial mission being undertaken.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) notes the following thruster bared zones.

> *17.17.1 Barred Zones are used to prevent thruster wash in certain directions. They are used to avoid thruster to thruster interaction, interference with hull mounted acoustic transducers, ROV launch area, etc. Care must be taken to test these thoroughly as incidents have occurred when a barred zone has been active even not required. For example, when barring is active for an adjacent thruster even when it is stopped and barring is no longer required. In such cases the barred thruster is unable to produce thrust in the direction of the stopped thruster and position is lost.*

THRUSTER MODES

As well as bias there are other modes that can be allocated in the DP system depending on the type of vessel and type of thrusters.

Many DP systems will enable a fixed mode for a thruster and this is when the DPO can fix an angle and thrust for one or more thrusters, though care needs to be taken as this limits the ability of the DP to utilise all the thrust that would otherwise be available.

On anchor handlers with very large and powerful main propellers often the DP will offer a ‘push/pull’ mode. This is similar to having a bias mode on the main props, so one will be ahead and one will be astern. Two things to note here. The first is that the rudder associated with the ahead propeller will be the only one to provide athwartship thrust and second that the two props are creating a turning moment. This can be a useful feature to ‘assist’ slightly the bow thrusters, so it may be advantageous to define Port Ahead or Starboard Ahead depending on the environment.

If the DPO considers it appropriate they can select ‘free’ mode and this is where the DP is free to allocate any thrust and direction to all selected thrusters.

THRUSTER AND GENERATOR OPERATING STRATEGY (TAGOS)

MTS DP Operations Guidance - part 1 paragraph 1.2.10 recommends the use of a Thruster and Generator Operating Strategy (TAGOS)

> *This is a document that provides informed guidance, usually derived from a review of the FMEA and if necessary, validation from personnel knowledgeable about vessel specific information, on appropriate configurations of thrusters, generators and power distribution, and associated constraints, so as to enable correct choices to be made to provide optimum level of redundancy.*

DNV-GL's document Dynamic positioning systems - operation guidance state that the DP operations manual should represent the way the vessel is operated, and that,

> *For complicated power systems and/ or thruster configurations, it may be useful provide the operator with a thruster and generator operating strategy (TAGOS) to assist in the decision on what generators and thrusters to use for different circumstances and different equipment availabilities.*

They also suggest that additional DP capability plots correlated to the TAGOS be provided on the vessel.

THRUSTER CONTROL SYSTEM - THE BASICS INCLUDING EM STOPS AND EMERGENCY/BACKUP CONTROLS

DP control systems operate on the same basic control system principles as any other control system. Where significant differences exist, it is in the type and range of protection functions provided, the means of detecting faulty position and sensor data and the means of dealing with internal faults. DP control systems can be distinguished by their thruster interfaces.

MSC.1/Circ 1580 - GUIDELINES FOR VESSELS AND UNITS WITH DYNAMIC POSITIONING (DP) SYSTEMS

States:

> *3.3 Thruster system*
>
> *3.3.1 Each thruster on a DP system should be capable of being remote-controlled individually, independently of the DP control system.*
>
> *3.3.2 The thruster system should provide adequate thrust in longitudinal and lateral directions, and provide yawing moment for heading control.*
>
> *3.3.3 For equipment classes 2 and 3, the thruster system should be connected to the power system in such a way that paragraph 3.3.2 can be complied with* ***even after failure of one of the constituent power systems and the thrusters connected to that system.***
>
> *3.3.4 The values of thruster force used in the consequence analysis (see paragraph 3.4.2.4) should be corrected for interference between thrusters and other effects which would reduce the effective force.*
>
> *3.3.5* ***Failure of a thruster system including pitch, azimuth and/or speed control, should not cause an increase in thrust magnitude or change in thrust direction****.*
>
> *3.3.6 Individual thruster emergency stop systems should be arranged in the DP control station. For equipment classes 2 and 3, the thruster emergency stop system should have loop monitoring. For equipment class 3, the effects of fire and flooding should be considered.*

IMCA M103expands in these requirements and give guidance on how thrusters should fail (if they do fail) so as to minimise the impact on the vessels station keeping ability.

> *2.18 Thrusters, Main Propellers and Rudders*
>
> *Unlike some other parts of the DP system, thrusters and their control systems can fail in such a way as to cause a drive-off. Such failures can be compounded by load shedding measures. If a large thruster fails to full thrust when there is insufficient spinning reserve, the power management system may command a phasing back of thruster rpm or reduce pitch for all thrusters. As the faulty thruster cannot respond to the command to reduce load the effect is to exaggerate the drive-off as the healthy thrusters are no longer able to oppose the faulty unit.*
>
> *Unlike thrusters provided with hydro-mechanical CPP mechanisms, fixed pitch propeller (FPP) thrusters driven by variable frequency drives very rarely fail to full thrust. DP rules and guidelines generally require thrusters not to fail in such a way which results in an uncontrolled increase in thrust or change in thrust direction. Fail safe conditions are taken to be*
>
> - *fail as set*
> - *fail to zero thrust;*
> - *drive motor trips.*
>
> *Although almost all thrusters now exhibit a failsafe response to the type of faults simulated during DP FMEA proving trials, the extent to which thrusters and their local control systems are truly fail safe is not well established. Very few thruster control systems have a completely independent protection system monitoring the performance of the thruster. An unambiguous alarm should be given for a command/feedback deviation and not for a wire-break.*

The very low incidence of failures to full thrust in FPP thrusters tends to place this issue well down on the list of DP failure modes to be addressed.

Although it would be relatively simple to develop independent monitoring and protection systems for thrusters it is important not to reduce reliability by introducing a system which can spuriously trip one or more thrusters. IMCA M 216 – Thruster integrity management guidance – provides further guidance by presenting and describing a thruster integrity management system for thruster units installed on a new build and existing vessels.

MTS DP Vessel Design Philosophy Guidelines (Rev2 - Apr21) offers guidance on assessing the effective force on the vessel being produced by the thruster. This is in the context of the capability plots but offers useful insights into real world conditions:

6.4.1 The thrusters generate the counter forces necessary to establish the force equilibrium. A realistic assessment of the actual thruster net forces acting on the vessel is a prerequisite for accurate polar plots.

6.4.2 The following should be considered when assessing actual thruster net forces:

The basic thruster performance data should be based on sound hydrodynamic principles, not on marketing considerations.

The thruster data used for generating capability plots at different current inflow velocities should be based on performance curves for that inflow velocity. Using bollard pull data which is usually based at zero inflow velocity leads to inaccuracies.

The potential impact of current inflow on thrusters that are not aligned with inflow should be considered.

The thruster performance data provided is usually for open water conditions. Thruster data used for station keeping calculations should account for thruster to hull interaction losses. The magnitude of the losses is a function of the hull shape, thruster location, degree of tilt of the propeller or nozzle axis, etc.

'Barred zones' prevent thrust in defined sectors. These zones can be created in the DP control system software to address issues associated with thruster wash for azimuthing thrusters. Such barred zones may result in reduced capability. Typically, the arc of this sector is small and the associated losses are a few percent of the nominal thrust.

100% thruster power in DP is not always the actual 100% power due to scaling the thruster in DP within a linear range. Some drives are tuned 0-80% or similar leaving less power available in DP.

The thruster power used for generating capability plots should be based on the actual maximum power achievable in DP control.

Propeller performance if provided at all will tend to be 'bollard' condition (i.e. assuming no inflow into the propeller) and will be a curve of thrust/power versus Speed. For propulsion propellers we often see a set of 'Robinson Curves' and these show the relationship between speed and thrust at increasing inflow rates (i.e. as if the vessel were sailing). We observe some of this effect if the vessel is in DP in a real current. So with an inflow the thrust as a particular propeller speed will be less than we calculate from the bollard condition.

THRUSTER DRIVE SYSTEMS

Thruster drive systems can be:

- Electric motors - AC induction, synchronous (salient pole machines), DC (less frequently used).
- Hydraulic motors.
- Direct drive by diesel engine.

Electric motor driven thrusters are most common in DP service. Thrusters that are driven directly by diesel engines are common in logistics vessels. Some vessels are outfitted with thrusters powered by hydraulic motors.

Most modern-day electric motors for thrusters are powered by AC variable speed drives. The characteristics of these drives are a good match to the characteristic of a propeller. The drive system can deliver a constant torque to the nominal speed and power and then over that rpm range of the motor the torque reduces to keep the power constant (approximately 110 to 115% of the nominal rpm). This feature is similar to the field weakening feature of older DC/SCR controlled systems; however, it utilizes simpler motors, and operates at higher efficiencies.

A thruster drive system for a DP semisubmersible, for instance, can be designed to deliver power to match the propeller characteristic the thruster over the entire operating range of the vessel. In this case, the thruster propeller pitch is selected for bollard pull. By increasing the rpm (by field weakening), full power is available even at a transit speed of 5 to 7 knots.

For a typical DP monohull vessel, the operating range is too large to utilize the field weakening effectively. The propeller pitch must be optimized between bollard pull and transit to deliver an effective thruster. However, the thrust required for transit is normally way beyond anything required for DP.

Thrusters (or in-line main propellers) with fixed pitch propellers driven directly or through a reduction or reverse/reduction gear by Diesel engines are not able to control the lower part of the engine rpm below the engine's minimum idling rpm, which is may be 40% of the rated rpm. Operating the diesel engine in this range with a clutch leads to high wear of the clutch and is not desirable. Where thrusters are driven by diesel engines, control of thrust in magnitude and direction (ahead/astern) is best achieved by a controllable pitch propeller.

EMERGENCY STOPS

ABS GUIDE FOR DYNAMIC POSITIONING SYSTEMS 2021

Emergency Stop (1 March 2021)

An emergency stop facility for each thruster is to be provided at the main DP control station. The emergency stop facility is to be independent of the DP control systems, manual position control system and manual thruster control system. The emergency stop facility is to be arranged to shut down each thruster individually.

This emergency stop is to be arranged with separate cables for each thruster.

Electrical cables potentially exposed to hydrocarbon fires in engine rooms and spaces where fuel oil is contained these cables are to be fire-resistant coated.

An alarm is to be initiated upon loop failure (i.e., broken connections or short-circuit) in the emergency stop system.

The emergency stop activation buttons are to be placed in a dedicated layout representing the thruster location and which is consistent with the vessel's axis and layout, or they may be arranged together with the corresponding thruster levers if these are arranged in accordance with the physical thruster layout. Where an accidental operation of the emergency stop buttons can occur, a protective cover is to be mounted.

Emergency stops for thrusters are to be located within easy reach of the DP operator (DPO) e.g., within the bridge, at the main DP control station.

Emergency stops for thrusters are to be laid out in a logical manner which reflects the position of the thruster in the vessel's hull.

For equipment classes 2 and 3, the thruster emergency stop system is to have loop monitoring.

ABS GUIDE FOR DYNAMIC POSITIONING SYSTEMS 2021 states:

9 Control Mode Selection

9.1 Manual/DP Control Modes *(1 November 2013)*

A simple device is to be provided in the DP control station for the selection of the thruster control modes (i.e., manual thruster control, Manual Position Control and DP control). The device is to be designed so that it is always possible to select manual thruster controls after any single fault in the DP control mode.

Thrusters within the DP control system may also be individually de-selected from DP control to manual thruster control for service and vessel specific operations.

9.3 Main/Backup Control Station

For **DPS-3** notation, the mode selector between main DP control station and backup DP control station is to comply with redundancy requirements. The transfer to the backup DP control station is to be fail-safe, so that if the main DP control station is damaged in any way, transfer of control can still be initiated and assumed at the backup DP control station. Transfer of control to the backup DP control station is to be performed manually, such that inadvertent control transfer to an unattended station is avoided.

Let's remind ourselves of some basics.

IMO MSC/Circular 1580 defines failure as,

> *an occurrence in a component or system that causes one or both of the following effects:*
>
> *.1 loss of component or system function; and/or*
> *.2 deterioration of functional capability to such an extent that the safety of the vessel, personnel or environment protection is significantly reduced.*

And a hidden failure as

> *means a failure that is not immediately evident to operations or maintenance personnel and has the potential for failure of equipment to perform an on-demand function, such as protective functions in power plants and switchboards, standby equipment, backup power supplies or lack of capacity or performance.*

Worst-case failure design intent (WCFDI) means

> *the specified minimum DP system capabilities to be maintained following the worst-case failure. The worst-case failure design intent is used as the basis of the design. This usually relates to the number of thrusters and generators that can simultaneously fail.*

And Worst-case failure (WCF) means

> *the identified single fault in the DP system resulting in maximum detrimental effect on DP capability as determined through the FMEA.*

The vessel's failure mode effect analysis (FMEA) will systematically analyse all systems and sub-systems to a level of detail that identifies all potential failure modes down to the appropriate sub-system level and their consequences.

The FMEA may identify several faults that all result in the WCF condition, and although many single line diagrams look symmetric in terms of power and thrust in fact the location of the thrusters on the hull will normally result in one RG failure being worse than another.

Therefore, the failure modes of any particular thrusters, on any particular ship, with any particular redundancy WCFDI are idiosyncratic.

For example consider the azimuth thruster system diagram below.

The FMEA might identify such as the following:

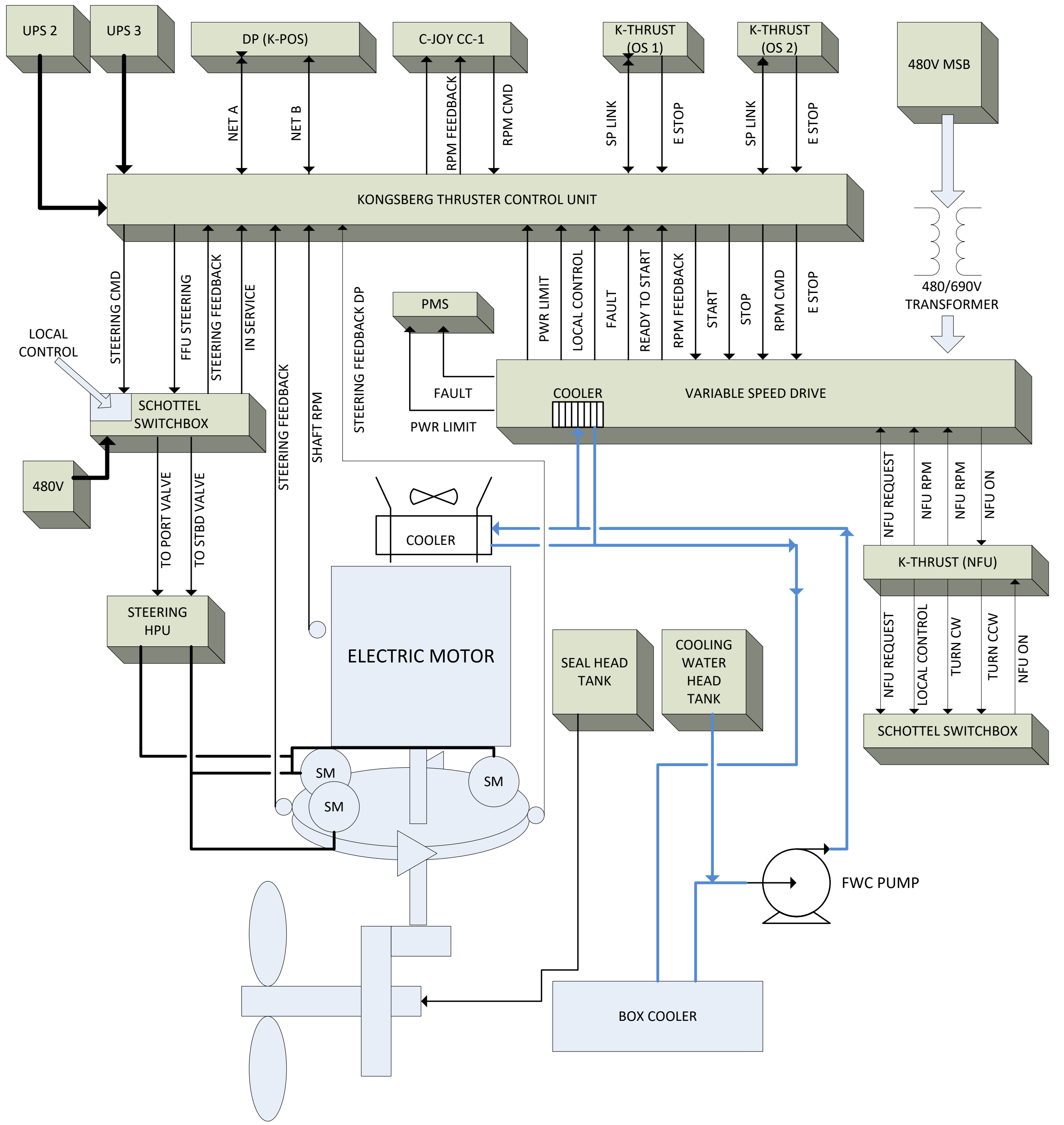


FIGURE 46 - EXAMPLE AZIMUTH THRUSTER SYSTEM DIAGRAM

Problems with the hydraulic oil, such as contamination, could result in erratic or delayed thruster azimuth and eventual wear and damage to the steering pump internals. It is important that the correct filtration is used for the oil and a program of regular oil sampling and analysis is implemented for all thrusters. However, in mitigation any single azimuth thruster's deteriorated steering capability will be compensated for by other thrusters and position loss should not occur. The Operator will be alerted to the correct thruster for shutdown by a command and feedback error.

Any failure of a hydraulic or LO circuit will only affect one thruster. Alarms are provided for hydraulic, lube oil pressure and temperature, tank levels, pump status, filters, etc.

Thruster shutdowns will be initiated by low servo pressure.

The effects of incorrect thruster speed control signals could range from a minor change in RPM to a thruster full RPM setting. A minor change may have little or no effect on position keeping ability and the DP system will *attempt to compensate with the other thrusters. A thruster failing to full RPM would require DPO intervention to deselect the thruster or emergency stop the thruster if the force could not be overcome.*

A failure of the thruster speed command signal will result in the thruster RPM going to the idle setting. This will have little effect on the vessel's position keeping ability as the remaining thrusters will be able to compensate.

The effects of incorrect thruster direction control signals could range from a minor change in direction to an incorrect direction setting. A minor change may have little or no effect on position keeping ability and the DP system will attempt to compensate with the other thrusters. A thruster failing to a direction opposite of what is required would require DPO intervention to deselect the thruster or emergency stop the thruster if the force could not be overcome.

The effects of incorrect steering box indication on the Azimuth thrusters cause incorrect steering data being sent to the TCU and DP system. The DP system uses the incorrect data in its force calculations and the DP model becomes unreliable. The DP system will attempt to compensate with the other thrusters, however the DPO may have to deselect or stop the thruster if the force could not be overcome.

A failure of the 'DP in command' signal to the Azimuth thrusters will cause the thruster ready contact to open and the thruster to take commands from the manual control stations. If the control levers on the manual control stations are not at the zero position, thrust will be applied. Operators are to keep manual controls in the zero position when in DP mode to prevent position keeping instability upon thrusters coming out of DP.

These failure modes could also be presented in tabulated format as below

Thrusters and Propulsion Failure Modes

Azimuth Thruster Control

Failure Mode	*Causes(s)*	*Probability*	*Local Effect*	*Final Effect*	*Criticality*	*Remarks*
Loss of VSD running signal to Kongsberg	Open circuit	Low	Thruster continues to follow DP commands however DP deselects thruster	Thruster not ready on DP. Thruster deselected.	Minor	Remaining thrusters compensate
Loss of VSD local control signal	Short circuit	Low	Thruster to idle. DP deselects thruster	Thruster not ready alarm on DP. Thruster deselected	Minor	Remaining thrusters compensate
Loss of Kongsberg speed command	Open circuit.	Low	Thruster VSD to idle. RPM feedback alarm	Thruster RPM to idle. Thruster continues to run	Minor.	
Incorrect speed command	Corrupted data	Low.	Thruster effect from unstable RPM to full RPM	Thruster RPM feedback alarm.	Medium	Thruster at full RPM would require DPO intervention to stop the thruster
Loss of Kongsberg speed feedback	Open circuit.	Low.	Thruster continues to operate on estimated feedback.	Thruster RPM feedback alarm. Thruster continues to operate on estimated feedback	Minor.	
Incorrect speed feedback	Speed pick up failure	Low	Thruster continues to follow DP speed commands	Thruster RPM feedback alarm. DP model calculations can be effected	Minor	Position keeping will weaken if other thrusters cannot compensate
Loss of thruster stop signal	Short circuit	Low	Thruster motor stops. Deselected from DP	Thruster 'Not Ready' alarm on DP. Thruster not available	Minor	Remaining thrusters compensate
Loss of converter fault signal	Short circuit	Low	Thruster stops. Deselected from DP	Thruster 'Not Ready' alarm on DP. Thruster not available	Minor	Remaining thrusters compensate

Thrusters and Propulsion Failure Modes

Azimuth Thruster Control (continued)

Failure Mode	*Causes(s)*	*Probability*	*Local Effect*	*Final Effect*	*Criticality*	*Remarks*
Loss of converter 24V control power	Open circuit	Low	Thruster converter fails. Loss of thruster	DP and VMS alarm. Thruster not available	Minor	Remaining thrusters compensate
Loss of electric Lube Oil pump	Mechanical / Electrical failure	Low	Thruster shuts down	Thruster not ready alarm on DP	Minor	Remaining thrusters compensate
Loss of hydraulic pump.	Mechanical / Electrical failure	Low	Thruster shuts down.	Thruster not ready alarm on DP. Azimuth frozen. Motor stopped	Minor.	
Low hydraulic pressure	Mechanical failure	Low	Thruster shuts down.	Thruster not ready alarm on DP. Azimuth frozen. Motor stopped	Minor.	
Loss of Schottel steering command signal	Open circuit	Low	Steering box opens healthy signal and freezes direction. RPM to idle	Thruster not ready alarm on DP. Thruster deselected	Minor	
Loss of steering box control feedback	Open circuit	Low	Steering box opens healthy signal and freezes direction. RPM to idle	Thruster not ready alarm on DP. Thruster deselected	Minor	
Loss of steering box indication feedback	Open circuit	Low	Loss of MTC and DP steering data.	DP system detects fault and uses estimated thruster performance to command	Minor	
Mechanical feedback link	Mechanical failure	Low	Incorrect control and indication feedback. Thruster fails to rotate	Thruster steering appears frozen. Heading and position control may weaken	Major	DPO intervention required. Deselect thruster if position keeping is threatened

DP Event Bulletin	ITEMS
IMCA DP Station Keeping Bulletin 04/19 November 2019	Steering motor failure leads to loss of both aft thrusters – DP incident
IMCA DP Station Keeping Bulletin 04/19 November 2019	Pipe leak leads to loss of all thrusters – DP incident
IMCA DP Station Keeping Event Bulletin 03/16 September 2016	Separate problem with two thrusters caused loss of DP

NEW DEVELOPMENTS IN LAST 5 YEARS

The need for improved efficiency, cost-effectiveness, and environmental sustainability in the maritime industry have driven developments to thruster systems. The use of advanced propulsion systems and control technologies will continue to play a crucial role in the design of dynamically positioned vessels.

SRP-D RUDDER PROPELLERS FOR SOVS

Propulsion system specialist Schottel, Spay, Germany, has introduced a new rudder propeller optimized for DP use.

Meeting the growing requirements for W2W (walk-to-work) vessels to operate efficiently and reliably, the new SRP-D is a further improved rudder propeller variant for highly demanding DP operations by service operation vessels.

"With the SRP-D, we have significantly increased the DP performance of our rudder propellers, resulting in a product that meets the requirements of today's offshore wind industry even better," says Manfred Heer, vice president-technology at Schottel. "Based on the proven principle of the Schottel Rudder Propeller, a cost-efficient yet powerful solution has been developed that greatly improves the positional accuracy of the vessel for the special DP requirements of these applications. For customers, this means a significant increase in safety and possible operating times on offshore structures, especially in difficult weather conditions."

FIGURE 47 - TYPICAL RETRACTABLE AZIMUTH THRUSTER (1)

In developing the SRP-D, extensive CFD simulations and calculations were taken into account. The new SRP-D variants are characterized, above all, by reduced propeller acceleration/deceleration times. In combination with a high-speed azimuth steering system with reinforced gear components, the SRP-D enables faster thrust allocation than conventional rudder propellers. With shorter response times, it is possible to react faster and in a more targeted manner to external forces from wind, weather and currents, thus achieving a higher positional accuracy of the vessel. At the same time, fuel consumption is reduced.

In addition, the SRP-D has an extremely low profile, vertically integrated LE-Drive and an additional 8-degree tilt of the lower gearbox.

Despite its integrated design, the LE-Drive allows a free choice of motor for vessels with an electric, ideally battery-supported, energy supply. Due to its compact design, the LE-Drive opens up more freedom in vessel design.

The SRP-D is optionally also available with the drive train in Z-configuration.

Thanks to an additional lower gearbox downward tilt of eight degrees, the interaction between propulsion unit and hull as well as the propeller flow interaction are reduced. This results in increased thrust efficiency in DP operation and minimizes "forbidden zones."

UNDERWATER DEMOUNTABLE AZIMUTH THRUSTERS

Underwater demountable azimuth thrusters are designed for easy underwater mounting and dismantling without dry-docking the vessel. This is of utmost importance to large vessels and semi-submersible oil drilling rigs to continue operation without any delays. Dynamic positioning thrusters are in service 24/7 during drilling operations. Interrupting drilling and leaving the site in order to repair a unit would be a costly decision.

There are three main components of the underwater installation system. The receptacle with the outer cap (top), the inner cap (middle), and the thruster (bottom). The inner and outer caps are installed at the factory and shipped to the site. Once installed into the vessel the outer cap is removed to access the inner cap. The inner cap is then removed to reveal the hydraulic steering motors and attachment for the cardan drive shaft.

WATERJETS

Waterjets are available in four model sizes ranging from 1000kW to 4000kW to accommodate vessels from 15m up to 45m with stainless steel jets supported by a complete range of electronic controls with joystick docking. These high performance units are specially designed and built for continuous commercial use and to meet the exacting standards of marine classification societies. They can be installed as single or as multiple jets in fiberglass, aluminium or steel hulls. They can also be supplied as booster jets.

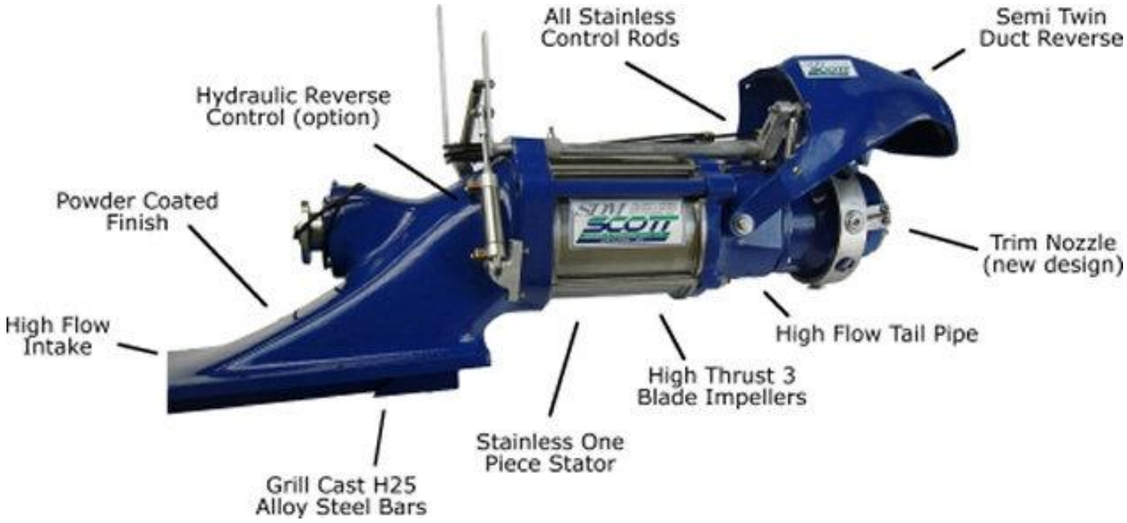


FIGURE 48 - TYPICAL WATERJET

The prefabricated duct is manufactured from Aluminium or Steel plate material resulting in an extremely strong and lightweight structure.

FIGURE 49 - TYPICAL RETRACTABLE AZIMUTH THRUSTER (2)

Electric retractable thrusters are fixed pitch propeller thru-hull azimuth thrusters capable of retracting completely into the hull. They are configured for vertical variable speed electric motor input.

Sizes range from 250 to 10,750 HP (185kW to 8.0MW) with a wide selection of reduction ratios and propeller/nozzle diameters to suit the application requirements. They are normally supplied complete with electric motors and variable frequency drives, but they can also be made to fit flange and shaft end of a customer supplied or shipyard supplied electric motor. The motor travels up and down with the thruster, so the drive line is never disconnected.

Electric retractable thrusters can supplied with an open propeller or with a nozzle. They are also available as combination thrusters, functioning as tunnel thruster in the retracted position and freely azimuthing in the lowered position. Compact units are available for vessels with limited hull depth. A hull fairing piece is normally attached to the bottom of the thruster to reduce drag when the thruster is stowed.

Whilst not new, the Voith Schnieder propellers have been used more extensively in recent years for offshore vessels.

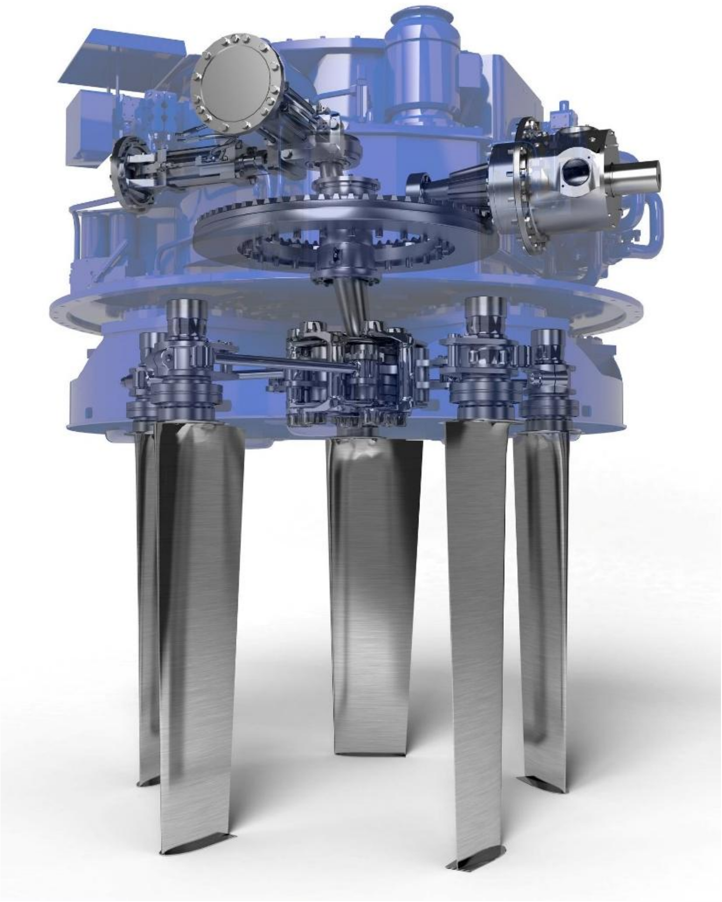
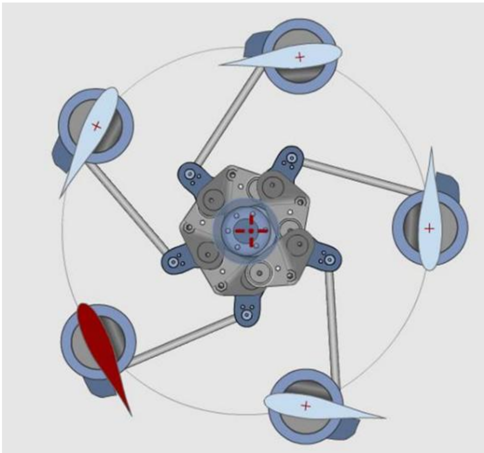


FIGURE 50 - VOITH SCHNIEDR PROPELLER



Clicking on the picture above will take you to the Voith Website where an animation of the propeller principle is available.

As the assembly rotates, the linkages adjust the angle of attack of the vertical blades causing then to all direct the water on one direction.

The advantage is that magnitude and direction of thrust can be changed very rapidly.

DP Operations
Operational Planning & Decision Support Tools
General operational planning – configuration of DP systems (CAM / TAM) and ASOG to define operational, environmental and equipment performance limits applicable when operating vessel and provide guidance on actions in the event of these limits being exceeded.
DP alert light system
DP setup procedures
DP watch keeping procedures
Environment conditions

IMO MSC/Circular 1580 states that,

> *4 OPERATIONAL REQUIREMENTS*
>
> *4.1 Before every DP operation, the DP system should be checked according to applicable vessel specific location checklist(s) and other decision support tools such as ASOG in order to make sure that the DP system is functioning correctly and that the system has been set up for the appropriate mode of operation.*

Although IMO MSC/Circular 1580 applies to vessels and units constructed on or after 9 June 2017 and that vessels and units constructed on or after 1 July 1994 but before 9 June 2017, may continue to be apply the previous version of the Guidelines (MSC/Circ.645), *it is recommended that section 4 of the present Guidelines be applied to all new and existing vessels and units, as appropriate.*

to define operational, environmental and equipment performance limits applicable when operating vessel and provide guidance on actions in the event of these limits being exceeded

ASOG

IMO MSC/Circular 1580 defines an ASOG as:

> *1.2.1 Activity-Specific Operating Guidelines (ASOG) means guidelines on the operational, environmental and equipment performance limits for the location and specific activity. (For drilling operations, the ASOG may be known as the Well-Specific Operating Guidelines (WSOG)).*

IMCA M 130 define an ASOG as

> ***3.5.4 Activity Specific Operating Guidelines (ASOG)***
> *An ASOG defines the operational, environmental and equipment performance limits for the location and the specific activity the vessel is undertaking. The performance limits are established based on the level of risk. A DP vessel may have several different ASOGs, each applying to different locations, activities and levels of risk. The terms well specific operating guidelines (WSOG), field specific operating guidelines (FSOG) and location specific operating guidelines (LSOG) denote equivalent concepts as applied by specific offshore sectors.*

The ASOG should be developed by those who have appropriate knowledge and understanding of the vessel and its expected operations. Although the development process may involve external specialists this does not alter the strong recommendation that the vessel crew should own the ASOG documents and the processes used to develop them, from inception through to implementation. Importantly, the master and DPOs of the vessel should be involved throughout.

Discussions on the ASOG should be carried out prior to the DP vessel starting operations. These discussions should involve the vessel's master, DPOs, chief engineer, engineer/electric/electronics officers as appropriate and may be included as part of the pre-arrival procedure.

All parties with an interest in vessel activity based operational planning should agree on the contents of the ASOG. And there should be a signature section at the end of the document.

Where a DP vessel is operating at a charterer's offshore installation it is recommended that the ASOG is signed by a representative of the charterer as well as the master, chief engineer and the DPOs. The charterer's representative may be a shore based superintendent or, where possible, the OIM of the offshore installation.

The ASOG should be displayed at the DP control console and in the engine control room. It should be clearly visible to the DPOs and engine room watchkeepers and used by them in setting up and operating the vessel for DP operations as well as providing them with a range of responses to degraded conditions in each mode.

182 MSF Rev. 2 – April 2015 - International Guidelines for The Safe Operation of Dynamically Positioned Offshore Supply Vessels suggests that consideration should be given to the following when developing an ASOG

- *Capabilities of the vessel, for both the intact condition and degraded condition following a worst case failure (WCF) as defined by the FMEA study and appreciation of the limitations imposed upon operations in the degraded condition after such a failure;*
- *An understanding of the limitations imposed by weather conditions, water depth and tidal influences on the vessel's position keeping capability;*
- *Consequences of a loss of position and/or heading both within and out of the limits that have been predetermined in the ASOG;*
- *Simultaneous operations (SIMOPS) and the effects of vessel interaction when the DP offshore supply vessel is operating in close proximity to other vessels, including the consequences of any change in status of own vessel or other vessels, e.g. Green to Blue, Yellow or Red;*

- *The activity being performed and the necessary time delay to safely terminate that activity before being able to manoeuvre the vessel to a safe position following a failure;*
- *A central component in the ASOG is a proven knowledge of black out recovery capability and time.*

An ASOG table uses four columns: green (normal), blue (advisory), yellow (degraded) and red (emergency).

	Green	Blue	Yellow	Red
Definition	Normal operations – all systems fully functional and operating within acceptable performance limits	Advisory status – approaching performance limits or reportable alarm status. Operations may continue whilst risks are being assessed. A failure has occurred that does not affect DP redundancy	Reduced status Pre-defined performance limits reached, component or system failure resulting in loss of redundancy	Emergency status – pre-defined operational or performance limits exceeded, component or system failure resulting in loss of control or position, internal or external emergency situation affecting the vessel
Response	For DP operations to commence and continue the conditions in the GREEN column must be met	Conduct risk assessment to determine whether to continue, change position or cease operations	Commence preparation to safely terminate operations. Specific guidance for vessel types is available in the appendices	Abandon operations. Take immediate action, i.e. initiate emergency disconnect sequence (EDS) to ensure the safety of people, the environment, the operation and the vessel

182 MSF goes on to list typical items that might be contained in the ASOG as:

- *Maximum watch circle radius (if applicable) for worst weather conditions identified for that activity;*
- *Maximum environmental operating conditions, including wind speed and current limits, and wave height;*
- *Weather specific vessel positioning performance, including position and heading excursions;*
- *Maximum offsets permissible from the set point position;*
- *Drive off, drift off scenarios;*
- *Diesel generators, including the minimum number required for the activity, performance limits and failures;*
- *Diesel generator loading;*
- *Thrusters, including the minimum number required for the activity, performance limits and failures;*
- *Thruster loading;*
- *Batteries;*
- *Power management system (PMS) and vessel management system (VMS) status of operation;*
- *Auxiliary systems performance limits and failures, including fuel, seawater and freshwater cooling and compressed air;*
- *Uninterruptible power supplies (UPS) operation, charger output, supply status and failures; DP control system, including operation and performance of DP controllers and failures; DP control system displays, including mimics, performance and failures;*
  DP networks, including operation, redundancy and failures;
- *Position reference systems, including number and types of enabled systems, suitability, performance and criticality to operation and failures;*
- *Sensors, including number of enabled systems, performance and criticality to operation and failures;*
- *Communications, including onboard systems, performance and failures;*
- *Non-essential DP related systems, including ventilation and air conditioning performance and failures;*

- *Fire, flood, visibility, collision, including threat to the DP operation; Simultaneous operations, including communications with assets.*

Very helpfully 182 MSF contains an example of Activity Specific Operating Guideline (ASOG) of which we supply a sample below although we recommend that you read this document in full.

Activity Specific Operating Guidelines – Name of Logistics Vessel				
This set-up applies when the vessel is carrying out DP supply operations within the 500m zone of an offshore facility				
Condition	**Green**	**Advisory**	**Yellow**	**Red**
Notify master, chief engineer, client rep (if on board) and rig/ platform	**NO**	**YES**	**YES**	**YES**
Action	**Continue normal operations**	**Informative/ consultative status (risk assessment)**	**Safely terminate operations and be ready to move off. Vessel to safe position and on joystick or manual if applicable. Orderly removal of the vessel from the 500m zone if necessary**	**Cease operations – leave 500m zone immediately**
Weather forecast	Within operating limits	Approaching operating limits	Exceeding operational limits	
Checklists: 6H; watch; 500m	Completed	Not completed or abnormalities noted		
Drive off	All systems operating correctly	Immediately when recognised by DPO		Unable to bring vessel under control
Drift off	All systems operating correctly	Immediately when recognised by DPO		Unable to bring vessel under control
Vessel footprint/weather related excursion	On position	Position limits reach 3m (10 ft)	Approaching 5m (15 ft)	
Heading excursion	On heading	Heading limit reached 3 degrees	Approaching 5 degrees	
Heading and position control (thruster load/ DP feedback)	Heading and position control achieved with <45%	Approaching 50%	More than 50%	
Shaft generators SG1-2	SG1 and SG2 online, AG1 and AG2 standby. No alarms	Any other set-up or alarms	Any generator failure	
Shaft generator loads	Both generators <45%	Any SG approaching 50%	Either >50%, or failure of a generator	
DP UPSs	No UPS in bypass, no alarm	Any UPS in bypass or alarm	Loss of one DP UPS	
24Vdc system	All 24Vdc active and fully charged, no alarms	Any alarms	Loss of a 24Vdc system or charger failure	
Main propulsion (drive engines and rudders)	Both enabled, no alarms	Any other set-up, any alarms or poor control	Loss of either port or starboard	
Bow thrusters available	Both enabled, no alarms	Any other set-up, any alarms or poor control	Loss of any bow thruster	
Stern thrusters available	Both enabled, no alarms	Any other set-up, any alarms or poor control	Loss of any stern thruster	
Fuel systems	No alarms	Any sign or potential threat or fuel oil contamination, supply line blockage, or any other supply failure	Loss of any generator due to fuel oil contamination, line blockage, or any other supply failure	
DP control system (power mimics)	All displays check and up to date	Any incorrect information	Incorrect information that affects DP operation	
DP control system (controllers/operator stations)	All controllers and operator stations online	Any alarms or poor performance	Loss of one network	
DP network	Both networks available, no alarms	Any alarms or poor performance	Loss of one network	Complete loss of networks

FIGURE 51 - 182 MSF REV. 2 – APRIL 2015 (International Guidelines for the Safe Operation of Dynamically Positioned Offshore Supply Vessels)

GREEN indicates NORMAL OPERATIONS. DP status is GREEN where all items in the GREEN column are met, indicating that the vessel is able to maintain position with adequate redundancy in all critical systems, and have the ability to handle expected environmental variations.

BLUE is an ADVISORY condition which applies to all operations or situations where the vessel HAS NO IMMEDIATE RISK of losing position, but something has occurred that requires a re-evaluation of the risk. Any ADVISORY status should immediately start the risk assessment process. The vessel cannot remain in any ADVISORY status without the DPO taking action. After a comprehensive risk assessment, operations may continue with mitigating measures in place where the ADVISORY status may be decreased to GREEN. The outcome of the risk assessment process, however, could also mean increasing to YELLOW preparing to cease operations.

There are no conditions where ADVISORY status should be considered or treated as a normal situation. If the DP system is fitted with consequence analysis this may trigger an ADVISORY status.

An example of the ADVISORY DP status is a failure of one of the main engine starting air compressors. This failure would not normally create a risk to activities that do not consume supplied air but the vessel should postpone any activity that would use a lot of air until the backup compressor is repaired.

YELLOW is a WARNING condition indicating there is a high risk of the vessel losing position should another failure occur. The vessel is still maintaining position although some DP critical equipment will have lost redundancy. In YELLOW DP status, operations the vessel is undertaking should be stopped so that contingency procedures can be initiated, such as getting ready to disconnect a hose line and moving to a safe location. If the DP system is fitted with consequence analysis this may trigger YELLOW status.

An example of YELLOW DP status would be the loss or failure of one bow thruster where the vessel is only fitted with two. In this example redundancy has been lost. The vessel would still be able to maintain position but would lose position if the remaining bow thruster failed.

RED indicates a severely degraded status or emergency. A RED status should immediately initiate a disconnection with all DP reliant operations terminated since the vessel may be losing position.

When RED DP status is initiated it is essential to inform all relevant personnel immediately.

An example of a RED DP status would be a fire in a DP critical compartment or space.

CAM AND TAM

IMCA M103develops the support documents for risk based planning and control to include the creation of CAMs and TAMs. We recommend that you access and read IMCA M 103.

> ***3.5.2 Critical Activity Mode (CAM)***
> *The CAM defines the most fault-tolerant configuration for the DP system and associated equipment. CAM should be implemented for all critical activities undertaken by the vessel. For DP class 2 and 3 vessels the CAM will ensure that a single point failure does not exceed the vessel's identified worst case failure. Where it is permissible to operate with a lesser standard of fault tolerance then the CAM may be replaced by a TAM.*
>
> ***3.5.3 Task Appropriate Mode (TAM)***
> *A TAM is a risk based operating mode in which the DP vessel may be configured and operated such that a single point failure could result in exceeding the vessel's identified worst case failure. A TAM may be applied where a risk assessment has demonstrated that the consequences of exceeding the vessel's identified worst case failure are acceptable.*

As with the ASOG CAM's and TAMs should be developed by those who have appropriate knowledge and understanding of the vessel and its expected operations. Although the development process may involve external specialists this does not alter the strong recommendation that the vessel crew should own the CAM and TAM documents and the processes used to develop them, from inception through to implementation. Importantly, the master and DPOs of the vessel should be involved throughout.

Discussions on the CAMs and TAMs should be carried out prior to the DP vessel starting operations. These discussions should involve the vessel's master, DPOs, chief engineer, engineer/electric/electronics officers as appropriate and may be included as part of the pre-arrival procedure.

All parties with an interest in vessel activity based operational planning should agree on the contents of the CAM and TAM. And there should be a signature section at the end of the document.

Where a DP vessel is operating at a charterer's offshore installation it is recommended that the CAM and TAM is signed by a representative of the charterer as well as the master, chief engineer and the DPOs. The charterer's representative may be a shore based superintendent or, where possible, the OIM of the offshore installation.

The ASOG should be displayed at the DP control console and in the engine control room. It should be clearly visible to the DPOs and engine room watchkeepers and used by them in setting up and operating the vessel for DP operations as well as providing them with a range of responses to degraded conditions in each mode.

182 MSF Rev. 2 – April 2015 (International Guidelines for The Safe Operation of Dynamically Positioned Offshore Supply Vessels suggests that consideration should be given to the following when developing an ASOG

CAM and TAM refer to the system and equipment configurations of DP vessels.

For example, a CAM may require the DP vessel to operate with open bus ties whereas a TAM may permit the vessel to operate with closed bus ties.

A CAM may require a minimum of three independent position references based on different principles whereas a TAM may accept two.

A DP MODU may operate in a CAM where time to terminate an operation in an emergency is long, such as when non-shearable heavy wall drill pipe is passing through the BOP, but in a TAM when time to terminate is short.

IMCA recommend a CA and a TAM for all DP vessels regardless of DP class. A DP vessel will normally have one CAM and TAM, although some vessel owner/operators decide not to operate in TAM.

It is the responsibility of the vessel owner/operator to provide them and they should be based on:

- a thorough knowledge of the DP system;
- the DP FMEA;
- the industrial mission;
- vessel location, and
- risk assessment.

Any DP vessel, including DP class 2 and 3, can have the redundancy concept defeated if its systems and equipment are not configured and operated in the correct manner. The purpose of a critical activity mode of operation is to detail in a clear and unambiguous manner how to configure a vessel's DP system, including power generation, distribution, propulsion and position reference systems, so that the DP system, as a whole, meets its maximum level of redundancy, functionality and operation and is as fault tolerant and fault resistant as it can be. For DP class 2 and 3 vessels the CAM usually defines the most robust fault tolerant configuration of the DP system, ensuring that a single point failure3 does not result in a condition exceeding the vessel's identified worst case failure.

The CAM gives tabular guidance to the operator (DPO) on actions to take when the CAMO configuration is not met.

Every DP vessel has a unique CAM configuration. A CAM configuration is derived from a detailed review of the vessel's DP FMEA4 and its operational characteristics. The CAMO configuration should be the default operational mode for a DP vessel, when conducting activities deemed to be critical.

It is suggested that the results of the above review are summarised in a vessel overview document (VOD). The VOD serves as a useful tool to onboard crew as well as on-coming personnel and others involved in the vessel's operations. This should be included in the DP operations manual.

A CAM table typically uses only two columns; GREEN (Normal) and BLUE (Advisory).

	Green	Blue
Definition	Normal operations – all systems and equipment fully operational, DP verification processes completed and DP set up confirmed.	Advisory status – where any GREEN conditions are not met.
Response	For DP operations to commence and continue the conditions in the GREEN column must be met.	Conduct risk assessment to determine whether to continue, change position or cease operations.

182 MSF Rev. 2 – April 2015 (International Guidelines for The Safe Operation of Dynamically Positioned Offshore Supply Vessels lists some typical items contained in the CAMO include the following:

- Power plant set up, including whether operating with open or closed bus ties;
- Diesel generators, including confirmation of 100% output in DP;
- Thrusters including confirmation of 100% output in DP;
- Power management, including configuration confirming that auto stop is disabled and black out recovery start is enabled;
- Uninterruptible power supplies (UPS), including confirmation of power supply, function testing, and absence of cross connections;
- Manual controls and independent joystick, including confirmation of readiness and testing of operation;
- DP control system, including availability of consequence analysis, mode availability and selection;
- Position reference systems, including number, availability, testing and selection, absolute or relative systems, polling, optimum placing of targets for type and local area of operation;
- Setting of vessel centre of rotation; such as bow, mid-ships and stern;
- Setting of heading rotation speed and speed of vessel moves; for example 10 degrees per minute and 0.3 m/sec, respectively;
- Sensors, including availability, testing and selection;
- Fuel systems, including confirmation of redundancy, tank levels, standby pump starts, isolations and crossovers;
- Sea water cooling, including confirmation of redundancy, standby pump starts, isolations and crossovers;
- Fresh water cooling, confirmation of redundancy, standby pump starts, isolations and crossovers;
- Compressed air/control air, confirmation of redundancy, safest compressor operating mode;
- DP and engine room manning, including watchkeeping schedules, qualifications and competency of watchkeepers; Trials and checklist completions.

Task Appropriate Mode (TAM) is a risk based mode and should be derived from a comprehensive risk assessment process. Task appropriate mode is how to configure and operate the vessel's DP system, accepting that a failure could result in a condition exceeding the vessel's identified worst case failure possibly leading to blackout or loss of position.

A TAM configuration is a choice that is consciously made. This mode may be appropriate in situations where it is determined that the risks associated with a loss of position are low and will not result in damage to people, environment or equipment.

The conditions under which a DP offshore supply vessel may operate in TAM should be defined and could, for example, relate to operations well clear of the 500 metre safety zone of floating or critical subsea assets and where the consequences of a loss of position have been evaluated and deemed acceptable.

EXAMPLE Critical Activity Mode of Operation – Name of Logistics Vessel				
No TAM operations permitted				
This set-up applies when the vessel is carrying out DP operations within the 500m zone of an offshore facility – AFI (agreed for implementation)				
Date				
Vessel to be set up and stabilised on DP before entering the 500m zone. Exiting the 500m zone may be done on joystick, manual or DP				
Condition	**Green**	**Advisory**		
Notify master, chief engineer, client rep (if on board) and rig/ platform	**NO**	**YES**		
Action	**Continue normal operations**	**Informative/ consultative status (risk assessment)**		
Switchboard set up	All bus ties OPEN	Any other configuration		
SG1, SG2, AG1 and AG2 (testing)	SG1 and SG2 online. AG1 and AG2 standby	Any other set-up, or problems found		
Emergency generator	Selected to auto start and available for immediate use. Auto start/connect and load tested prior to arrival on field	Any other configuration or known deficiencies reducing redundancy		
Blackout drill (single fuel system)	Blackout drill conducted for all DPOs and engineers onboard, procedures in place	Any DPOs on watch or engineers not performed blackout recovery drill in last six months		
DP power supply	All UPS units fully functional, not operating on bypass and tested on load 24 hours prior to field arrival. Note: Batteries must be at optimum charge level before entering 500m)	Any other configuration or known deficiencies reducing redundancy or endurance. Not tested for 30 minute endurance prior to field arrival		
24Vdc power systems (load test)	All fully functional with DC10 and DC20 cross connect breakers open (breaker F3 open in both panels) plus DC30 and DC40 cross connect breakers open (breaker F3 open in both panels). 30 minute battery endurance test carried out on DC10, DC20, DC30, DC40, DC50 24 hours prior to field arrival. Note: Batteries must be at optimum charge level before entering 500m)	Any other configuration or known deficiencies reducing redundancy or endurance. Not tested for 30 minute endurance prior to field arrival		
24Vdc power systems (battery chargers)	All on main feed to charger	Any other set-up or problems found		
Main engines (drive)	Operational and tested to 100% at field arrival	Engine not capable of 100% command or problems found		
Propellers and rudders (configuration)	One pump running on each (seawater cooling, freshwater cooling, steering pumps) with standby pumps ready for operation	Any other set-up or loss of any rudder		

FIGURE 52 - TYPICAL CAM - 182 MSF REV. 2 – APRIL 2015 (International Guidelines for the Safe Operation of Dynamically Positioned Offshore Supply Vessels)

POSITIONING STANDBY

'Positioning standby' is a heightened state of alertness initiated during the vessel's DP operation and may be triggered by a number of different conditions. It is initiated to bring all station keeping critical elements (equipment, people and processes) to a higher state of readiness, for a defined period, with the objective of preventing a loss of position.

'Positioning standby' ensures that:

- All necessary equipment is available and/or running;
- All personnel are in position to quickly respond to an event and so prevent an escalation.

The initiation of positioning standby' may initiate:

- A change in configuration from TAM to CAMO;
- Immediate or planned cessation of non-critical activities.

Examples of 'positioning standby' are:

- Heavy lift operations;
- Increase in time to terminate; Deteriorating weather;
- Station keeping equipment issues;

PRACTICAL ONBOARD EXERCISE

Read, know and understand your vessel's ASOG, CAM and TAM. Are there any differences between the CAM and TAM?

DP ALERT LIGHT SYSTEM

IMO MSC/Circular 1580 states that the DP control station means a workstation designated for DP operations, where necessary information sources, such as *indicators, displays, alarm panels*, control panels and internal communication systems are installed and that,

> *Alarms and warnings for failures in all systems interfaced to and/or controlled by the DP control system should be audible and visual. A record of their occurrence and of status changes should be provided together with any necessary explanations.*

A system of lights and audible alarms should indicate the DP system status at the appropriate operational/control locations. The required responses to a change in alert level should be determined by risk assessment and documented in tabular format in the ASOG.

IMCA M103defines the colour and sound of alarms and this complements the colour codes in the ASOG, CAM and Tam documents for each vessel type. We recommend you read the document in full and provide the DP Status for a dive support vessel below.

The red alert, accompanied by a distinctive alarm, should additionally sound in the master/OIM's cabin, operations superintendent's cabin (if applicable) and the senior diving supervisor's cabin (if applicable). A local means of acknowledging and silencing these alarms and flashing lights should be provided.

Normal status – GREEN light. Full DP diving operations can be undertaken.

- The DP system is operating as intended;
- Operational, environmental and equipment performance criteria as defined within the ASOG are all categorised as normal;
- The vessel could maintain position in the prevailing environmental conditions after the worst case failure.
-

Advisory status – If an indicator light is used then it is recommended that this be BLUE however alternative arrangements not involving the use of an indicator light are acceptable. Relevant personnel should be notified. Operations can continue whilst risks are being assessed.

- Operational, environmental or equipment performance limits are being approached;
- The DP system is no longer configured as required in the CAM/TAM;
- An advisory condition exists as defined in the ASOG;
- A failure has occurred that does not compromise single-fault tolerance of the DP system.

Degraded status – YELLOW light. The diving supervisor should instruct the divers to suspend operations and move to a safe location. The DPO, after consulting the diving supervisor, should decide if further action is necessary. If the diving supervisor is unable to get clear advice from the DPO then the divers should be instructed to return to the bell or deployment device and obtain a seal or to return to the surface as appropriate.

- A failure in the DP system has occurred leaving the DP system in an operational state but with its DP redundancy compromised. An additional failure in that system may result in an inability to maintain the vessel's position;
- The vessel's position keeping performance is deteriorating or unstable;
- The vessel would be unable to maintain position in the prevailing environmental conditions after the worst case failure;
- A 'yellow' condition exists as defined in the ASOG for abnormal operational, environmental and equipment performance conditions;
- Any other condition exists which may lead to a suspension of diving activities.

Emergency status – RED light with accompanying distinctive alarm. The diving supervisor should instruct the divers to return immediately to the bell (or deployment device as appropriate) and obtain a seal. The deployment device should be recovered as soon as possible after due consideration of hazards involved in the recovery. The DPO(s) should use all available means to limit the inability to maintain position while the divers are being recovered.

A system failure or other condition has occurred resulting in an inability to maintain position or heading control or to safely conduct diving operations;

- A 'red' condition exists as defined in the ASOG for hazardous operational, environmental and equipment performance criteria;
- Any other emergency situation which warrants immediate recovery of divers to a safe position.

It is critical to remember that IMO MSC/Circular 1580 states

> *4.3* ***DP operations necessitating equipment class 2 or 3 should be terminated when the environmental conditions (e.g. wind, waves, current, etc.) are such that the DP vessel will no longer be able to keep position if the single failure criterion applicable to the equipment class should occur.*** *In this context, deterioration of environmental conditions and the necessary time to safely terminate the operation should also be taken into consideration. This should be checked by way of environmental envelopes if operating in equipment class 1 and by way of an automatic means (e.g. consequence analysis) if operating in equipment class 2 or 3.*

ABOVE AND BEYOND

DP OPERATIONS GUIDANCE - PART 1 (Rev3 - Apr21)

Time to Terminate

Time to Terminate (TTT) is calculated as the amount of time required in an emergency to physically free the DP vessel from its operational activity following a DP abort status and allowing it to be manoeuvred clear and to proceed to safety.

For example: - In case of a DP drilling vessel this may be the time needed to release from the wellhead. For a DP diving vessel this may be the time needed for the diver(s) to return to the bell and make a seal so that the vessel can move clear. The Time to Terminate is not fixed for the duration of a DP operation but will vary according to the circumstances.

DP MODES OF OPERATION

There are several modes of operation that are commonly used in DP systems:

Automatic Mode: In this mode, the DP system is in full control of the vessel's position and heading. The system continuously adjusts the thrusters and other manoeuvring equipment to maintain the desired position.

Manual Mode: In this mode, the DP operator takes manual control of one or more of the axes (heading, surge, sway) usually with the joystick as the input device.

Auto track / Auto Sail Modes: In this mode, the DP system is used to maintain the vessel's position and heading during short transits to do specific activities (cable lay etc).

Auto Pilot Mode: the DP can be used to for longer transits typically where only propulsion thrusters are used for forward speed and steering.

In addition to these MTS DP VESSEL DESIGN PHILOSOPHY GUIDELINES (Rev2 - Apr21) offers notes on the following DP modes of operation.

Target Follow Mode: this enables the DP vessel to follow a moving target and is used, for example, to follow an ROV along a pipeline.

This is a feature that facilitates automatic change of position set- points to follow movements of another floating body. Examples of industrial mission which could benefit by this mode are:

1. *ROV tracking inspection work to automatically follow the ROV.*
2. *Positioning alongside a floating object susceptible to movement such as a TLP, Spar, MODU etc.*

   Note: Trials should be carried out prior to using Follow Target mode for operations described in (2) above. This mode requires the use of both absolute and relative position references. But "out of sync" measurements may be experienced in this mode and prevent its use. In such circumstances, positioning can be accomplished by using only redundant relative position reference sensors and conventional set-point auto DP mode.

3. *Functionality of the conventional follow target mode may need to be enhanced for industrial missions where relative positioning is required off targets which exhibit dynamic movements such as free weather-vaning FPSOs. Such functionality may require the provision of additional sensors and sub-modes. The burden of the development of detailed procedures and additional training requirements should not be underestimated.*

Heavy Lift Mode: This takes account of the effects of the load transfer on the mass of the vessel and the additional lateral force, normally by reducing gain and relaxing the DP controller.

This is a feature that is used to address potential instability caused by the stiffness imparted to the DP control systems during set down of the load (tonnes per meter offset). Note that the stiffness is related to the weight of the lift and the geometry of the lift height etc. Instability is not only related to mass but also to the vertical height from the end of the upper end of the lifting device to the load touch down point. The smaller the distance the greater the stiffness. For example, a relatively small load on an A frame with a shorter vertical height could result in destabilizing stiffness. There are known instances of A frames being damaged due to side loads imparted by instability. Vessels whose industrial mission includes lifting should evaluate the need to have heavy lift mode.

External Force Compensation: This is where the measured external force acting on the vessel, which is separate from the environment, is included in the DP calculation and treated as a force feed forward. This mode is used to account for pipe tensions in a pipe layer and hawser tension in a shuttle tanker.

When pipelaying, pulling in SCRs, hook-up of mooring lines etc. horizontal forces are exerted on the vessel. Vessels undertaking industrial missions where such forces can be experienced should be equipped with means for external *force compensation. Reliance on the DP control system treating such forces as 'learned' environment has and resulted in loss of position incidents with significant consequences.*

The input of forces values for external force compensation can be manual or instrumented. Systems designed to provide and accept input from instruments should be subjected to a robust fault tolerant and fault resistant systems engineering approach. Sensible limits should be applied to these inputs to avoid the DP control system responding to erroneous values.

Fire Monitor Compensation Mode: This is used to compensate for the varying forces exerted on vessel from the fire monitors.

DP vessels outfitted with fire-fighting capability as part of its industrial mission should address effects on DP control of forces related to azimuth, elevation and flow of fire nozzle water. If these are not compensated for directly the DP will consider them as an environmental force. Sudden loss of forces associated with water flow can cause a loss of position incident if inadequately compensated for by design.

Weathervane Mode: This enables the DP vessel to rotate with the wind, current and waves. This can be used when a vessel is operating alone, to minimise the thrust to save fuel etc. There are operations where a second vessel is involved (shuttle tanker off loading, etc) and then the DP controls the vessel around a fixed or moving point called the terminal point. Neither the heading nor the position of the DP vessel is fixed. The heading of the vessel is controlled to point towards the terminal point. The position of the vessel is controlled to follow a circle, called the setpoint circle, around the terminal point. This mode is appropriate for connected shuttle tanker/ FPSO operations.

A variant of this feature has also been used on semi-submersible hull forms with a four thruster configuration. This mode allows the vessel to weather vane using one thruster. The thruster is upstream and the vessel 'hangs' downstream due to current, wind, wave. The heading relative to the environment will depend on which thruster is available and the shape of the semi-sub. This is only meant to be a 'last ditch' mode to allow disconnection rather than drift off.

Monohull vessels with a predominantly aft super structure will naturally head into the wind like a weather vane. Similarly, they will tend to head into the current especially where there are high currents. It may be useful to the DP vessel to take advantage of these two effects when permissible by the industrial mission. Vessels that naturally weather vane as described above can be held on position and heading with a single bow azimuth thruster over the set point. This can be a mitigating feature in designs where the number of thrusters is limited and permits the vessel to bring itself to a safe condition post failure.

NOTE: It is not uncommon for the term "weather vane" to be used to denote "minimum thrust", i.e. where the DP control system allows the vessel's heading to rotate to minimize external forces acting on the vessel and thruster requirements. These terms should not be confused.

Shuttle tanker mode: This is a feature provided on DP tankers designed to offload product from offshore floating installations, typically turret moored FPSOs.

This mode is implemented to take advantage of weather-vaning capability of the FPSO and facilitate the industrial mission of the shuttle tanker without the need to provide it with a large transverse thrust capability. Shuttle tankers by design are provided with adequate thrust in the surge axis. Shuttle tanker mode optimizes thrust requirements on the shuttle tanker by allowing some freedom for misalignment with the FPSO.

Fast current update: This may be required for applications where the heading needs to be changed quickly e.g. mono hull MODUs or the direction of the current forces changes quickly. This is not strictly a 'mode' but a feature to update the model faster than normal. Often the DP will initiate the feature if a significant heading change is demanded.

This needs to be used with caution as the natural time constant of the DP loop in systems with model control is about 15 to 20 minutes. This time lag has been acceptable in most situations as a vessel responds slowly and the sea current typically changes slowly (wind compensation is feed forward). Fast current update decreases the time taken to 'learn' about a new situation. It should be recognized that any improper use of fast current update can *cause instability and other problems. This feature should not be used to compensate for lack of external force compensation mode.*

Track follow Mode: There are two types of track follow called Slow and Fast:

1. Slow Track Follow is used where fore/aft, port/stbd and heading are all controlled to keep the vessel on track or a fixed offset from it. This is typically used for pipe laying, SCR installation etc.

2. Fast Track Follow is used where the vessel heading is steered back towards the track. The heading change applied is broadly proportional to the port/stbd offset from the track. This is typically used for cable laying, seismic streamers, etc.

Axis priority select mode: DP control systems are designed by default to give priority to controlling heading when there is insufficient thrust. This is appropriate for monohulls. Such vessels have the potential to lose position more rapidly if thrust is not prioritized to control heading.

Some industrial missions may require priority in another axis. This should be specified during design, for example, vessels intending to operate beam on to a platform as a default.

GPS only operation mode: Nearly all DP vessels use GPS with some form of differential correction to enhance the accuracy of the raw GPS position calculation. This is not normally a 'mode', it requires the operator to reduce the quality checks on the GNSS data. Normally, the DP would look for a digit in the NMEA string indicating that the solution was corrected (either 'Differential' or 'PPP' etc) if this is not the case the fix would normally be rejected and alarmed. It is possible for the user to change this 'test' to allow the use of raw GNSS fixes. Great care should be taken to ensure that this is restored if a subsequent operation is undertaken requiring precise positioning!

However, raw GPS may be sufficient for use where the industrial mission does ***not require precision position accuracy***.

DP CONTROL MODE SELECTION

The DP mode control selector forms a common point between all thrusters. The design should ensure that a failure cannot cause the control mode to transfer from auto DP to another mode. In addition, accidental change of mode continues to be a cause of DP incidents so good design and careful operation is critical. IMCA M103states

The means by which control over the thrusters is changed from manual to DP to independent joystick (IJS) is a potential weak point in any DP system. No failure of the selector system should prevent manual control.

The control selector forms a common point between all thrusters. The design should ensure that a failure cannot cause the control mode to transfer from auto DP to another mode. For DP equipment class 3 vessels it is important to ensure no single failure of the control selector switch should cause control to transfer unexpectedly to the backup DP system. This can be achieved by having a separate digital communications interface from the control selector to each thruster field station.

Accidental change of mode continues to be a cause of DP incidents. Locating buttons with critical functions close to less critical functions increases the risk of a critical button being accidentally pushed. Good ergonomic design should position critical push buttons where they are unlikely to be operated inadvertently.

IMO MSC/Circular 1580 states that

*4.1 Before every DP operation, the DP system should be checked according to applicable vessel specific location checklist(s) and other decision support tools such as ASOG in order to make sure that the DP system is functioning correctly **and that the system has been set up for the appropriate mode of operation**.*

IMC M103specifies that there are five types of operational set up checklists that must be carried out.

3.4.5 DP Field Arrival T rials

These checks should be carried out on arrival at the field and conducted outside the 500 metre safety zone. The checks should be repeated when the vessel returns to the field after an absence of more than 24 hours.
The purpose of these checks is to ensure satisfactory operation of the DP system. The checks should include full functional checks of the operation of the thrusters, power generation, auto DP and independent joystick (IJS) and manual controls. The checks also ensure that the DP system is set up correctly and that the manning is adequate.

See also IMCA Information Note No. 1628 – December 2022 Field Arrival Trials

3.4.6 DP Location Set-up Checklist

These checks should be carried out at every working location and may be used as a routine checklist. Where the vessel is to visit a number of offshore installations on a voyage then these checks should be carried out every time the vessel changes from transit mode to auto DP mode.
The purpose of these checks is to ensure that the vessel's station keeping performance at the working location is satisfactory and, in particular, to ensure that the position reference systems are properly set up. The checks also provide a hard copy record of power and propulsion demands and DP control parameters.

Vessel heading should also be adopted at this time to ensure that thruster loads will be acceptable on the working heading and location. The initial stabilisation period should be at least 30 minutes, subsequent periods of stabilisation following moves and heading changes should be determined by the circumstances and conditions. The initial stabilisation period may be reduced to less than 30 minutes where it can be demonstrated that this will not have a detrimental effect on DP model and position keeping dependability, the risk profile of the activity should be considered.

3.4.7 Change of Watch Checklist

The change of watch checklist should include all checks necessary to confirm the status of essential DP equipment and to complete a routine check of the performance and settings of that equipment. The DP sections of this checklist should be completed again following any substantial reconfiguring of essential DP equipment during the watch. The oncoming DPO should verify the contents of this checklist prior to starting the DP watch.

3.4.8 DP Engine Room Check list

Before the vessel approaches within 500 metres of the work site or when requested by the DPO on watch an engine room readiness for DP operations checklist should be completed by the engineer on watch. The purpose of this checklist is to ensure that the engine room systems and equipment are set up correctly for DP with the correct redundancy and the appropriate equipment and switchboard configuration. Appropriate DP checks are additionally to be incorporated within the engine room change of watch checklist.

3.4.9 500m Zone Safety Checklist

These checks should be carried out each time before the vessel comes within 500 metres of any offshore installation.
The purpose of these checks is to ensure satisfactory operation of the DP system. The checks should also confirm that the DP system is set up correctly and that the manning is adequate and that the vessel has communicated with the installation and been given permission to enter the 500m zone.

Time and Date	:		/ /		:		/ /		:		/ /	
General												
Online computer	A		B		A		B		A		B	
Auto-switch on												
Consequence analysis	Off		Class 2		Off		Class 2		Off		Class 2	
Alarm page clear												
Vessel mode	Auto Pos		Follow Sub		Auto Pos		Follow Sub		Auto Pos		Follow Sub	
Gain	Low	Med	High		Low	Med	High		Low	Med	High	
Position set-point	N				N				N			
	E				E				E			
Vessel speed	m/s				m/s				m/s			
Limits pos/head	m		°		m		°		m		°	
Rate of turn	°/min				°/min				°/min			
Posplot range	m				m				m			
References												
Selected	DGPS1	DGPS2	TW	HiPAP	DGPS1	DGPS2	TW	HiPAP	DGPS1	DGPS2	TW	HiPAP
HiPAP Pole	Up		Down		Up		Down		Up		Down	
Transponder no.s												
Deployment												
Divers	In		Out		In		Out		In		Out	
Others												
Follow Target												
ROV	In		Out		In		Out		In		Out	
TP no./location												
Reaction radius	m				m				m			

FIGURE 53 - MSF 182 Contains a Sample Watch Keeping Handover Checklist (Part 1)

Sensors			
Gyros	1 2 3	1 2 3	1 2 3
Wind			
Compare			
Environment			
Wind dir/speed (T)	° kts	° kts	° kts
Current dir/speed (T)	° kts	° kts	° kts
Thrusters			
Online	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Mode	Var. 90/270	Var. 90/270	Var. 90/270
Set-point/F.back			
Rudder zero			
Power			
Generators online	1 2 3 4 5 6	1 2 3 4 5 6	1 2 3 4 5 6
Available	1 2 3 4 5 6	1 2 3 4 5 6	1 2 3 4 5 6
Clutched in	1 2 3 4	1 2 3 4	1 2 3 4
Available power	kW	kW	kW
Maximum used	kW	kW	kW
Communications			
Field			
Dive control			
ROV			
Deck/crane			
Others			
DPO Signature			

FIGURE 54 - MSF 182 Contains a Sample Watch Keeping Handover Checklist (Part 2)

In addition to these MTS DP Operations Guidance - Part 1 adds

DP Field Move Checks
These checks are particularly relevant to DP MODUs and drillships where moves are of short duration and take place inside the field. These checks are less intensive than Field Arrival checks since the rig remains on DP with BOP suspended. The checks ensure the DP system remains fit for purpose.

500m Checks

500m checks are not normally applicable to DP MODUs. All OSVs and other vessels should undertake 500m checks. Only vessels engaged in support activities to remain within the 500m zone of the DP MODU. The 500m zone is not to be used as a standby location unless required to support a specific activity.

Watch Status/ 6 Hour Checklist

The purpose of these checks is to record the status of the DP system and configuration. The checks should verify that the vessel's station keeping performance at the working location is satisfactory and, in particular, that the position reference systems are properly set up and operating satisfactorily. No testing is carried out for these checks. DPOs should complete the checklist prior to taking over the watch, not during the first few minutes of the watch.

The Marine Safety Forum have issue a document called Marine Operations: 500m Safety Zone that offers some practical advice on set up and operating in the 500m zone under these headings; approach passage & pre-entry; approach (500m - 200m approx.); position set-up; final approach (200m approx. - working position) & alongside working; exiting safety zone. We recommend that you read this document in full but a visual overview has been provided here for you

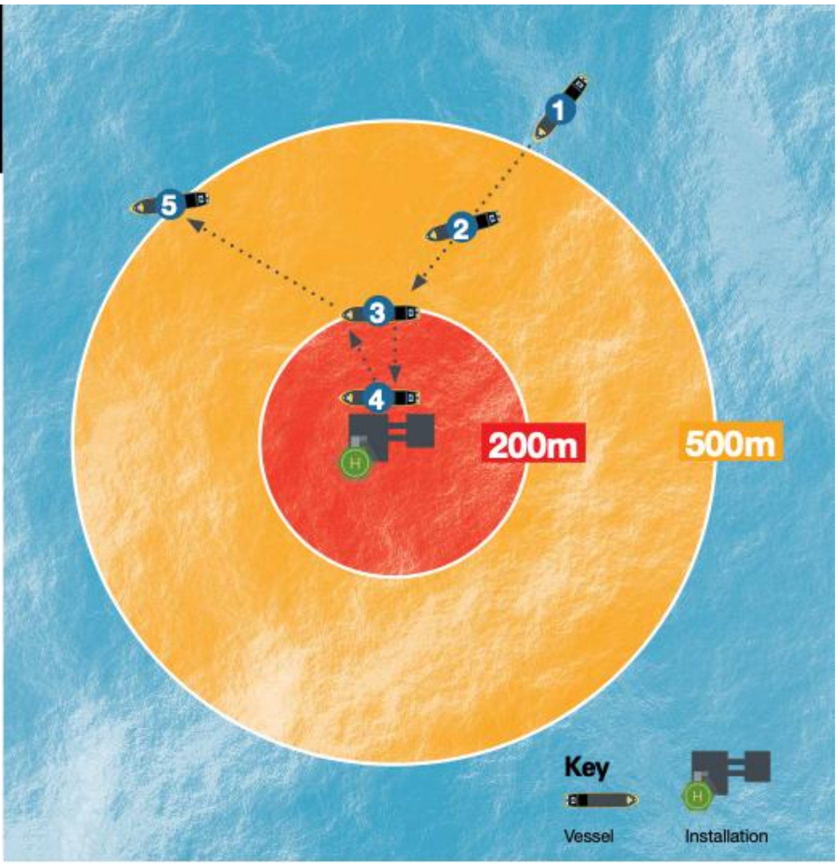
STEP CHANGE IN SAFETY

Produced in association with

MARINE Safety Forum

MARINE OPERATIONS 500M SAFETY ZONE

Pre-Entry > Set up > Working > Exit



1 Approach passage & pre-entry

- Vessel passage plans must not have installations as waypoints. Final waypoint must be offset from the installation
- Establish contact and ensure that radio-working channels are understood
- Pre-entry checks to be carried out in a drift off situation testing interaction / communications with installation. Determine who (on the installation) is responsible for maintaining contact with the vessel
- Should control of the vessel be transferred to another station (e.g. fwd to aft) or a different operating mode is selected (e.g. manual to full DP) then it should be ensured that all manoeuvring arrangements are responding as anticipated before undertaking any close proximity operations
- Discuss the planned approach and proposed work
- Any installation delays expected? Bulk transfer permits? Weather side working risk assessment? Installation staff availability? Notify vessel if any overboard discharges from the installation could affect operations
- DP reference system targets in correct position and ready (reflectors clean etc)
- Identify and set trigger and hold points which determine operation start/stop/hold or prompt a risk assessment or risk assessment review
- Vessel to confirm to installation once ready to enter safety zone

Only once the installation is fully satisfied that the vessel has undertaken the necessary pre-entry checks and that the work plan minimises the length of time the vessel will be required to be in close proximity to the installation should permission to enter the safety zone and proceed to the set-up location be given.

If it has been identified that working in a drift on condition will be required then, **before** permission to enter the 500m safety zone is given, a risk assessment must be undertaken by both the vessel and the installation, mitigations put in place as required and agreement between the OIM and Vessel Master made before allowing operations to be undertaken.

2 Approach (500m - 200m approx.)

Approach and work alongside installation to be made in the same mode as tested during pre-entry process. Should 'mode of operation' or control station be changed then the full range of system checks should be undertaken again to ensure that systems are operating correctly.

A correct approach should have the vessel coming alongside obliquely. The vessel should not approach head on.

- Speed to be 3 knots or less, depending on the vessel type and weather conditions
- Escape routes identified

The faster the vessel comes in the harder it could hit the installation!

3 Position set-up

This is the process whereby vessel personnel determine how adequately the vessel is managing to hold position before starting the final approach. This should be done far enough away so that, if something goes wrong, the vessel crew have enough time to take corrective action.

It can take some time to acquire a stable position and allow a DP model to build up (up to 30mins)

Position set-up to take place well away from the installation (position such that installation collision avoided if equipment failure occurs during set up checks)

- 1½ x vessel length for drift-off operations
- 2½ x vessel length for drift-on operations

During this time the vessel personnel are to satisfy themselves that:

- DP references and sensors are stable
- Vessel motion is within operational limits
- Vessel machinery operation within limits i.e. power utilisation not greater than 45%

4 Final approach (200m approx. - working position) & alongside working

Once satisfactory set-up checks are complete and permission has been given by the installation to move to the working location, the vessel should be manoeuvred towards the installation in incremental steps (circa 10m) at a time using progressively smaller steps.

If the operation is going to involve working in a 'drift-on' condition, then a joint (installation and vessel) risk assessment must be undertaken.

- Speed ≈ 0.5kts (0.3m/s)
- Minimum separation distances to be maintained

5 Exiting safety zone

Once operations are complete and the vessel is ready to depart the safety zone the following should occur:

- Confirm manifests / DG notes all on-board
- Hose(s) disconnected and clear
- Deck secure (sea fastened) for transit
- Vessel secure
- Move to set-up position
- Depart safety zone in a controlled manner following recommended speeds as per entry process
- Transfer controls once outside safety zone
- Once outside safety zone vessel to obtain instructions (client control etc.)
- Provide ETAs for next location

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FIGURE 55 - MSF - MARINE OPERATIONS: 500M SAFETY ZONE

IMO MSC/Circular 1580 states that

Personnel engaged in operating a DP system should have received relevant training and practical experience in accordance with the provisions of the 1978 STCW Convention, as amended, the STCW Code, as amended, and the Guidelines for Dynamic Positioning System (DP) Operator Training (MSC/Circ.738, as amended).

See also STCW

See also IMCA M 117

MTS DP Operations Guidance - Part 1 offers some guidance on manning a DP vessel including the following table.

Operation	Minimum Bridge Crew Per Shift	Minimum Experience
When undertaking critical activities in proximity to surface or sub surface structures. See Note 1 below.	2 unlimited DPOs on the bridge capable of operating the vessel both in DP and manual control. See Note 2 below.	Unlimited DPO with a minimum of 3 years experience on a vessel engaged in similar operations, at least 6 months of which should have been on the subject or sister vessel. Experience level should be documented and auditable. See Note 3 below.
Note 1	Critical activities are those activities where the consequences of equipment failure or loss of position are greater than under normal operating circumstances. For example, critical activities on a DP dive support vessel would include those occasions where the Time to Terminate is long, such as when the diver is inside a welding habitat or where the diver's worksite is inside the conductor tubes at a production facility.	
Note 2	The Master should not be considered as one of the required unlimited DPOs for meeting the manning requirements.	
Note 3	It is recognized that in practice, given the near term market conditions owners/ operators will be challenged to meet the recommended level of experience for DPOs. Owners/ operators should recognize the associated risk from inexperienced personnel and have plans in place to address them while striving to reach the recommended experience levels.	

FIGURE 56 - MANNING - MTS DP OPERATIONS GUIDANCE - PART 1

In addition it stats that for engineers:

4.16.2 Engineers - There should be sufficient licensed engineers on board for all expected operations.

4.16.3 At least one licensed engineer should be available at all times, should be on watch during critical activities and should have at least 6 months experience on similar equipment and operations.

4.16.4 The engineer should be fully cognisant of DP operations, familiar with the vessel's DP FMEA document and the effects of failures of equipment relating to the position keeping of the vessel.

4.16.5 In DP 2 or 3 operations, the engineer should be familiar with the general philosophy of redundancy as it relates to split mechanical, electrical and ancillary systems.

And for ETOs

> *4.16.6 Electrician/ Electrical Engineer – If required on board, an electrician should have appropriate high voltage training/ certification, if applicable to the vessel. As with vessel engineers, the electrician/ electrical engineer should have at least 6 months experience on similar equipment and operations.*
>
> *4.16.7 The electrician should likewise be fully cognisant of DP operations, familiar with the vessel's DP FMEA document and the effects of failures of equipment relating to the position keeping of the vessel.*
>
> *Notes Where the minimum experience requirements cannot be met a risk based approach should be taken to determine the suitability of personnel and any additional support requirements for intended operations.*

IMCA M 117 stresses the *importance of good team management* and states that owners/operators and suitable procedures should be put in place as required by the International Convention for the Safety of Life at Sea (SOLAS) and the International Convention on Standards of Training, Certification & Watchkeeping for Seafarers (STCW) Code. It also states that:

> *The concept of continuous professional development is to be encouraged for DP bridge and technical personnel.*

Interestingly IMCA M 177 states

> *If the DPO does not form part of the navigational watch, then they need not have a navigational watchkeeping qualification to current STCW Convention standard or flag state equivalent (this enables engineers and DP electrical and electronics technicians to be DPOs).*

And not many people know that! IMA M 177 does offer some guidance on the amount of time (or experience) DP key personnel should have and they acknowledge that when a vessel changes owners and/or operators, or is deployed in a new area, it may be difficult to crew the vessel with adequately experienced DP personnel.

	Previous DP Vessel		**Current DP Vessel**	
Key DP Personnel	**DP Hours**	**Weeks onboard**	**DP Hours**	**Weeks onboard**
Master/OIM	250	10	100	4
Senior DPO	250	10	150	2
DPO	150	3	50	1
Chief Engineer	250	10	100	4
Senior Engineer Watchkeeper	100	4	50	2
Engineer Watchkeeper	50	2	50	2
DP Electrical and Electronics Technician	250	10	100	4

FIGURE 57 - IMCA 117 - Recommended Minimum Experience on an Established DP Vessel

When joining a new vessel familiarisation is key.

<u>IMCA M 117 Minimum Period of Familiarisation on a Familiar Vessel</u>

A familiar vessel is considered in these guidelines as one that has the same DP control system, or the same type of engines and switchboard configuration and is or has been engaged in similar operations. If the equipment supplier is the same, this will not necessarily mean that the control system is 'familiar' because third and fourth generation DP control systems are likely to be quite different to operate, although the concept of operation may be the same. It can be helpful if vessel owners/operators indicate to clients those systems which are similar within their fleet.

For new personnel joining a vessel with a familiar control system that carries out critical operations such as diving support, drilling or operations close to installations, there should be a minimum period of familiarisation, as outlined in Table 3. This familiarisation activity should include a structured plan comprising a supervised programme of onboard familiarisation followed by assessment through a company authorised procedure.

Key DP Personnel	Minimum Familiarisation Period	
Master/OIM	24 DP hours	3 days at sea
Senior DPO	24 DP hours	3 days at sea
DPO	24 DP hours	3 days at sea
Chief Engineer	24 DP hours	3 days at sea
Engineer Watchkeepers	24 DP hours	3 days at sea
DP Electrical and Electronics Technician	24 DP hours	3 days at sea

FIGURE 58 - IMCA M 117 Minimum Period of Familiarisation on a Familiar Vessel

Recommended Minimum Experience on a New or Unfamiliar Vessel

A new or unfamiliar vessel is a new or different vessel to some or all of its key DP personnel. Key DP personnel joining a new or unfamiliar vessel should undergo a structured familiarisation programme. Anessentialpartofthisisasupervisedprogrammeofonboardtrainingfollowedbyassessment. A brand new or converted vessel has generally had owner's/operator's acceptance trials as well as commissioning and FMEA trials, all of which may provide an opportunity for key DP personnel to complete assessment tasks and become suitably experienced in less time than when the vessel enters service. The minimum period of familiarisation that has been found to be satisfactory in the past is set out in Table 2.

Where possible, previous DP vessel experience (see section 8.1) and instruction from manufacturers/suppliers is provided onboard during the following time periods or previously at the manufacturers/suppliers' facilities.

Key DP Personnel	Minimum Familiarisation Period	
Master/OIM	50 DP hours	7 days at sea
Senior DPO	50 DP hours	7 days at sea
DPO	50 DP hours	7 days at sea
Chief Engineer	21 days	including 7 at sea
Engineer Watchkeepers	14 days	including 7 at sea
DP Electrical or Electronic Technician	21 days	including 7 at sea

FIGURE 59 - IMCA 117 Minimum Period of Familiarisation on a New or Unfamiliar Vessel

IMCA DP Station Keeping Bulletin 02/19

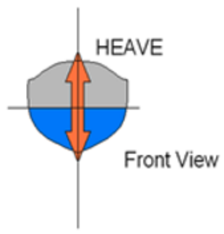
Unfamiliarity with DP system leads to – DP undesired event

THE BASICS

Dynamically positioning (DP) vessels have a computer-controlled system that automatically maintains its position and heading in a dynamic seaway by using its own propellers and thrusters.

THE ENVIRONMENT

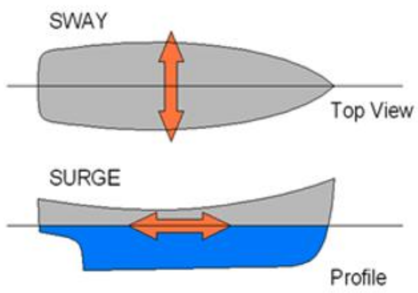
Vessels in a dynamic seaway experience six degrees of motion, or freedom:

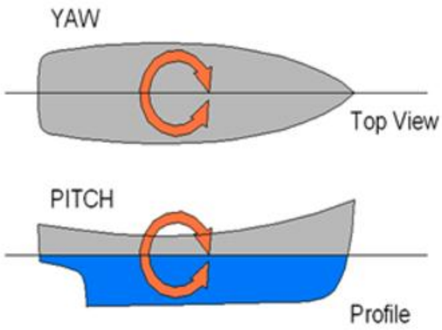


Heave is the linear vertical (up/down) motion

Sway is the linear lateral (side-to-side) motion

Surge is the linear longitudinal (front/back) motion





Roll is when the vessel rotates about the longitudinal (front/back) axis

Pitch is when the vessel rotates about the transverse (side-to-side) axis

Yaw is when the vessel rotates about the vertical (up-down) axis

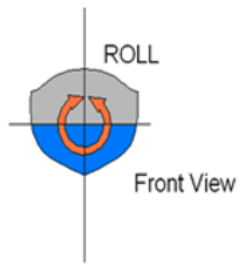


FIGURE 60 - THE VESSEL SIX DEGREES OF FREEDOM

The environment (wind, waves and current) acts on the vessel and creates movement in the 6 degrees described above. We know that the DP attempts to control Yaw, surge and sway. The vessel responds mostly due to waves in pitch, roll and heave.

For every DP vessel there is a maximum environment it can theoretically hold surge, sway and yaw (in its degraded state!)

There is one thing that can be relied upon and that is the environment will change! A critical part of the DPOs responsibilities is to monitor the environment with respect to thruster and engine loading. Predicting when the environment may cause problems is a judgement that come with experience, and it is far from theoretical.

In large wave conditions the smaller vessels, when they pitch the fwd tunnel thrusters come close to coming out of the water, and in that condition at that moment the thrust will be minimal.

One issue is the DP ability to hold heading and position well enough for the industrial mission to proceed safely. The other is with the current/wind/vessel motion can the industrial mission be performed (deck movement, lifting wind speed, sea current for divers etc). These decisions are not solely the responsibility of the DPO.

If the mission has to be paused it is vital that the time to terminate is clear to all (ASOG etc). Some can be terminated quickly (PSV deck lifts) while others take more time (pipelay abandon, ROV retrieval from deep water etc)

If the mission allows, changing heading relative to wave direction may help with roll/pitch etc

It is clear that being aware of published weather bulletins is vital, but some areas have rip tides local squalls etc and other challenges that are sometimes only observed by the crew.

At the other extreme if the environment is very benign the thruster loads may become small relative to the engine capacity, thruster bias modes may need to be adjusted. In such conditions heading may not be critical, but if the environment were to build it may be critical to change to an appropriate heading which may need the agreement of the industrial mission teams and may take time. Be prepared.

Unrelated to 'forces' are aspects of the environment such as snow, fog etc some of these can have an effect on the Position reference systems and some to the safety of the operation.

Some operations close to production units may mean that the crew has to be aware of contamination of the environment in terms of combustible gas etc. This would normally be part of the Risk assessment carried pout prior to the operation.

Most DP systems have an 'on line' capability plot function where the prospective environment can be 'tested' in terms of station keeping forces.

THE VESSSEL

Position reference sensors, combined with wind sensors, motion sensors and gyrocompasses, provide information to the computer about to the vessel's position, heading and the magnitude and direction of environmental forces affecting its position. These are all discussed in depth later.

The computer program contains a mathematical model of the vessel that includes information about the wind (above waterline) and underwater profiles of the vessel and the location of the thrusters. The mathematical model is adaptive, that is, it will 'learn' and continuously adapt to changes in the vessel or environment.

This knowledge, combined with the sensor information, allows the computer to calculate the required steering angle and thrust output for each thruster.

IMO MSC/Circular 1580 defines an a DP system as:

> *1.2.11 Dynamic Positioning system (DP system) means the complete installation necessary for dynamically positioning a vessel comprising, but not limited to, the following sub-systems:*
>
> *.1 power system;*
> *.2 thruster system; and*
> *.3 DP control system.*

and a DP control system as:

> *1.2.10 Dynamic Positioning control system (DP control system) means all control components and systems, hardware and software necessary to dynamically position the vessel. The DP control system consists of the following:*
>
> *.1 computer system/joystick system;*
> *.2 sensor system(s);*
> *.3 control stations and display system (operator panels);*
> *.4 position reference system(s);*
> *.5 associated cabling and cable routeing; and*
> *.6 networks.*

Below is a simple DP architecture diagram. The number, location, and configuration of the DP system components determines the vessels DP equipment class and its redundancy. This will be discussed later.

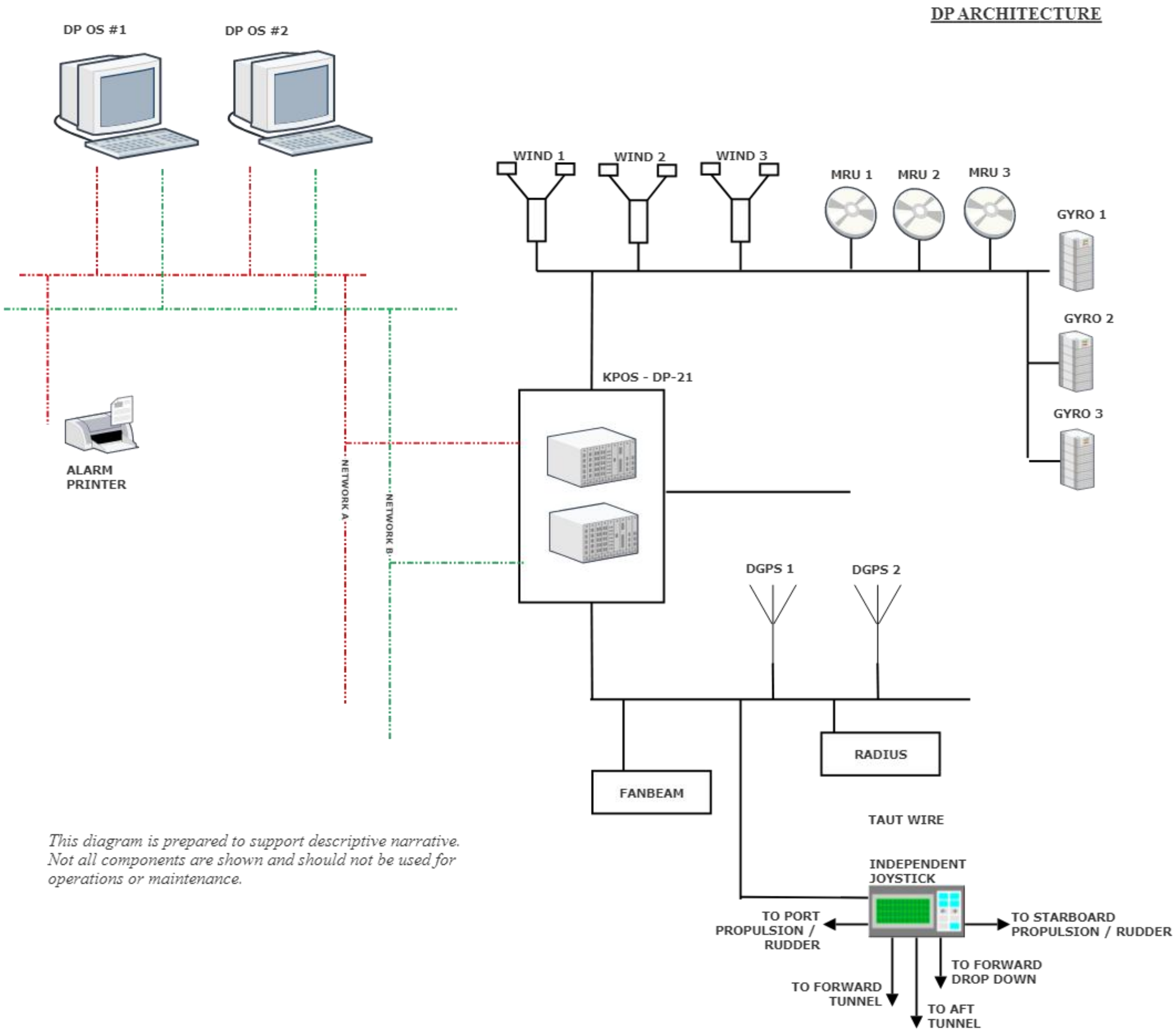


FIGURE 61 - Simplified DP Architecture

There is no single standard that addresses the development of a DP Operations Manual.

However, the importance of providing effective and unambiguous guidance to vessel operational teams has been acknowledged, especially given the demographics of the vessel operational teams, the dilution of skills prevalent in industry and limited experience in the conduct of the industrial mission.

TECHNICAL AND OPERATIONAL GUIDANCE (TECHOP) TECHOP (O-01 - Rev1 - Jan21) DP OPERATIONS MANUAL JANUARY 2021 offers the most comprehensive guidance on what should be in a DP Ops Manual. It states that the DP Operations Manual should contain relevant information on:

- *Company policies and procedures.*
- *Vessel specific information with emphasis on:*
- *The redundancy concept of the vessel.*
- *The configuration that achieves the highest level of integrity of the power plant and station keeping critical equipment (Critical Activity Mode – CAM).*
- *Alternate configurations (Task Appropriate Mode) that may be used.*
- *The process that is in place to identify operations that must be operated in CAM and those operations that can be operated in TAM.*
- *The processes that are in place to protect and defend the redundancy concept.*
- *The necessary training and drills required to be carried by the personnel tasked with delivery of DP operations.*
- *Industrial mission specific information.*

Usefully MTS have created a gap analysis tool in this TechOp so you can compare your DP operations manual with the requirements listed above.

IMCA M 109 A Guide to DP Related Documentation for DP Vessels Rev 3.1 October 2020 also offers a structure that the DP operations manual should follow. We recommend you access this document.

PRACTICAL ONBOARD EXERCISE

Find your vessel DP operations manual. Does it contain the chapters as outlined above. Are they in a user friendly format?

ABOVE AND BEYOND

Complete the gap analysis tool in TECHNICAL AND OPERATIONAL GUIDANCE (TECHOP) TECHOP (O-01 - Rev1 - Jan21) DP OPERATIONS MANUAL JANUARY 2021 for your current vessels DP operations manual

DP LOGS AND CHECKLISTS

See also DP Set Up Procedures

PURPOSE, OVERVIEW OF EXPECTATIONS / REQUIREMENTS

IMCA M 109 A Guide to DP Related Documentation for DP Vessels Rev 3.1 October 2020 suggests a list of DP related logs that should be kept onboard such as:

- *DP log describing times and dates of various DP operations, such as, for example:*
  - *vessel going into DP*
  - *diving or other operations requiring DP, for example:*
    - *times of diving bells leaving surface and reaching working depth*
    - *times of divers leaving/entering diving bell and reaching/leaving worksite*
    - *instructions that were received from dive/subsea operation control*
  - *other relevant activities depending on type of operation (for example as listed in 4.3)*
  - *key DP personnel coming on/going off shift*
  - *faults occurring in DP system(s)*
  - *times and details of connecting lines to installations;*
- *DP hours log with running total of time spent in DP;*
- *DP operator logbook which should give running total of time operator spends on DP operations (see for example the IMCA DP logbook);*
- *All data logging devices relevant to the DP operation including electronic, video, voice tape and any other.*

The following should also be available and kept up to date:

a file with a history of all relevant DP trials carried out on the vessel;

- a file with the results and recommendations of audits carried out on the vessel;
- a file of verifying footprints for the vessel. these should be checked occasionally against the capability plots to ensure they are accurate;
- a file with relevant drift trial data, verification of drift trial software;
- a file with the CVs of the key DP personnel;
- vessel DP familiarisation and training records;
- a maintenance file with records of all maintenance, including service reports, FMEA studies and modifications carried out on the DP system and related equipment including sensors;
- records of engine and thruster operating hours; records of engine and thruster lube oil and fuel oil analysis;
- records of power switchboard maintenance;
- records of communications systems maintenance.

IMCA M103includes a table of all the DP documenting you should have onboard.

CAPABILITY PLOTS AND FOOTPRINT PLOTS

CAPABILITY PLOTS

See section Capability Plots

Whilst the published Capability plots are required by class etc, they are of limited value to the DPO in the day to day operations. They are a very specific set of conditions, as they are really designed to compare vessel A with vessel B, and tend to be optimistic, looking for the 'biggest numbers'.

The DPO has the wind, wave, current magnitudes and directions on that day in that location. An indication of capability will be the thruster loads being used. This also allows an assessment of what the surviving thruster would run at if a WCF occurred.

The on-line capability can be useful to impose the WCF and to apply any predicted weather change.

FOOTPRINT PLOTS

The calculated position keeping capabilities which are provided by the DP capability analysis should be supplemented by real time measurements and observations. These real time observations and measurements are used to develop DP footprint plots.

DP footprint plots measure the vessel's real station keeping performance (accuracy) in specific equipment configurators and environmental conditions. They determine the vessel's actual position keeping ability in various thruster configurations and environmental conditions and can be used for comparison with DP capability plots.

DP OPERATIONS GUIDANCE - PART 1 (Rev3 - Apr21) state that DP Footprint Plots are

> *constructed, by observation onboard the vessel in real time conditions. The plots are of the vessel's DP station keeping performance and limitations in various environmental conditions (wind, seastate and current) and in various thruster/ power configurations, including all thrusters running, loss of most effective thruster and after worst case failure.*
>
> ***DP FOOTPRINT PLOTS***
>
> *4.5.1 DP Footprint Plots should also be produced on board. DP Footprint Plots are not theoretical. They are actual measurements of the vessel's DP station keeping performance in the actual environmental conditions and thruster configuration at the time the plot was taken. DP Footprint Plots should be taken whenever opportunities arise, such as during standby periods, weather downtime or on arrival at the field. Plots should be taken for the thruster configurations used in the DP Capability Plots, i.e. fully intact, loss of most effective thruster(s) and after worst case failure.*
>
> *4.5.2 Some DP systems have a software application that produces DP Footprint Plots electronically. DPOs can also produce DP Footprint Plots by manual methods using a plotting sheet.*
>
> *4.5.3 DP Footprint Plots serve two main purposes.*
>
> - *They provide a scatter plot of vessel positions at regular intervals around the required set position (this shows accuracy of station keeping)*
> - *They also provide comparison points on the limiting wind speed envelope given in the theoretical DP Capability Plots (this shows wind speeds at which it was seen that the vessel was unable to maintain position, thus validating or contradicting the theoretical DP Capability Plots for the various thruster configurations.)*
>
> *4.5.4 DP Footprint Plots serve other purposes, including learning and familiarisation opportunities for DPOs and in providing snapshots of vessel station keeping behaviour for specific locations and activities.*

4.5.5 Theoretical DP Capability Plots and DP Footprint Plots combine together to enhance knowledge and understanding of the vessel's DP station keeping ability.

Note DP Footprint Plots originated in harsh weather regions, such as in the North Sea. The plots are used to gain a better understanding of the vessel's actual station keeping performance and limitations in intact and, in various degraded thruster configurations, including worst case failure, whilst the vessel is being subjected to real environmental forces.

4.5.6 It is acknowledged that DP Footprint plots may be of less relevance to DP MODUs.

MSF 182 offers guidance for conducting DP footprint plots as follows

A DP footprint plot is designed to record the observed movement of the DP vessel from its desired target location over a period of time. Thruster configuration is selected at the beginning of the plot. The environmental forces of wind and waves are known from visual observation. Current is usually estimated.

A DP footprint is polar in outline with the bow, head up, at 0 degrees and the desired or target position is at the centre of the circle.

- *Select a safe location away from structures, other vessels, etc.;*
- *Make entries on the lines in the top right hand corner, identifying when, where and by whom;*
- *Indicate in the vessel outline which of the thrusters is selected and on line for the duration of the plot;*
- *Complete the environment boxes, putting a value against all of the forces and directions. Draw arrows on the plotting chart to indicate force and direction. Note that values for current should preferably be from an independent current meter. If not available, estimates for current from other appropriate sources include surface current charts and the DP estimated current;*

Indicate which of the position references are on line for the duration of the plot;

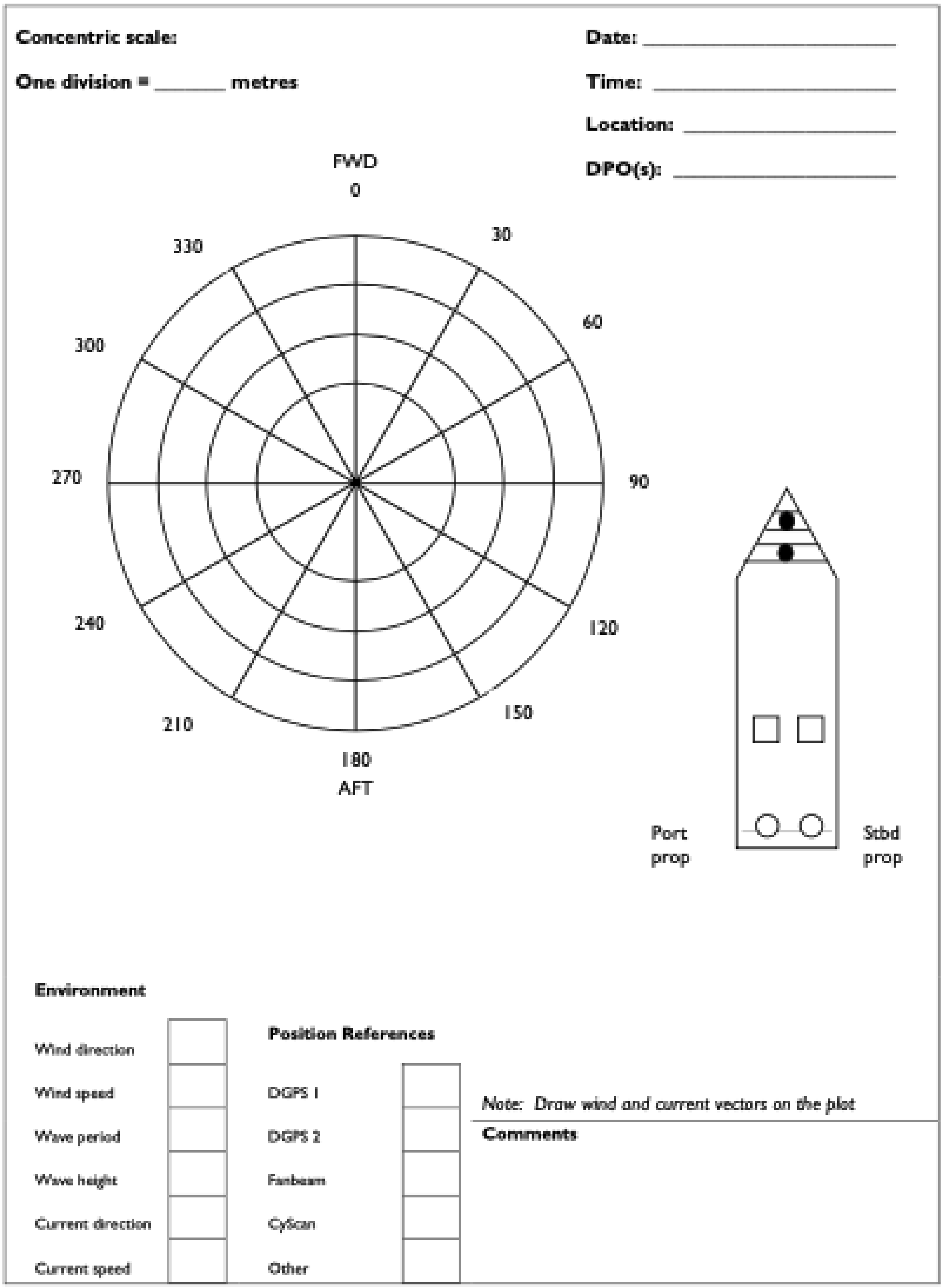
Select the concentric scale. One division could equal 1 metre, so that the total scale extends to 5 metres from the centre, or, if more vessel movement is expected, one division could equal 2 metres, hence increasing the total range to 10 metres from the centre;

Start plotting by marking with an X at regular intervals, say every 30 seconds, the observed position of the vessel in relation to the target position. The vessel's position can be taken from the DP system display screen;

Continue plotting until sufficient information is gained about the vessel's position keeping performance in the given environmental conditions. A completed plot will show the accuracy with which the vessel kept position. Plots can also show the occasions when the vessel is unable to keep position, i.e. when there is insufficient thruster force for the given environment. (This is a good check of the relevance of the calculated DP capability plots.)

DP footprint plots should be conducted whenever opportunities arise. Accumulated knowledge of the vessel's position keeping performance and the expected vessel excursions are helpful when selecting separation distance, critical and allowable excursion limits.

Note: A DP footprint is different to a DP capability plot. A DP capability plot shows by calculation maximum environmental conditions in which a DP vessel should not lose position.



Concentric scale:

One division = _______ metres

Date: ____________________

Time: ____________________

Location: ____________________

DPO(s): ____________________

Environment

Wind direction	
Wind speed	
Wave period	
Wave height	
Current direction	
Current speed	

Position References

DGPS 1	
DGPS 2	
Fanbeam	
CyScan	
Other	

Note: Draw wind and current vectors on the plot

Comments

FIGURE 62 - TEMPLATE International Guidelines for the Safe Operation of Dynamically Positioned Offshore Supply Vessels

CONSIDERATIONS FOR SIMULTANEOUS OPERATIONS INVOLVING DP AND NON-DP VESSELS

SIMOPS (simultaneous operations) are described as the potential clash of activities which could bring about an undesired event or set of circumstances, e.g. safety, environment, damage to assets, schedule, commercial, financial etc.

SIMOPS occur in marine operational activities associated with offshore operations in support of offshore exploration and production. SIMOPS are defined as performing two or more operations concurrently.

These activities typically include, but are not limited to, the following:

- A vessel undertaking a non-routine operation within an installation's 500m zone.
- Subsea umbilical's, risers and flowlines (SURF) operations.
- Field developments with multi-vessel/contractor operations.

Vessels include, for example, diving support vessels, heavy lift vessels, supply boats, barges, pipelay and cable lay, accommodation, seismic, survey, ROV vessels, and vessels operating in dynamic positioning mode. Installations cover, for example, fixed and floating production platforms, drilling rigs, DP production units, FPSOs and FPUs. SIMOPS often involve multiple companies (owners, contractors, subcontractors, vendors), large multi-disciplined workforces and a wide range of daily, 24-hour, routine and non-routine construction and commissioning activities.

It is important that SIMOPS are identified at an early stage before the work commences. SI MOPS may come about as the result of the following issues:

Schedule clashes, e.g. activities in same area at same time.

- Physical clashes, e.g. anchor patterns, loss of position.
- Failure impacts, e.g. explosions, leakage, gas etc.;
- Interference between platform operations and vessel operations;
- Contracts and third party interfaces, e.g. liabilities, risk/insurance;
- Environmental impacts, e.g. currents, icebergs, weather limitations;
- Territorial clashes, e.g. 500m zone, existing infrastructure;
- Any other combined/simultaneous activity in the area of operation which could compromise project success criteria.

IMCA have issued IIMCA M 203 Guidance on simultaneous operations (SIMOPS) and we recommend you read it. Below is an extract showing the life cycle model for SIMOPS.

DP Event Bulletin	ITEMS
DP Event Bulletin 01/22 – April 2022	Case Study – Masking of PRSs – SIMOPS

MTS Paper on SimOps

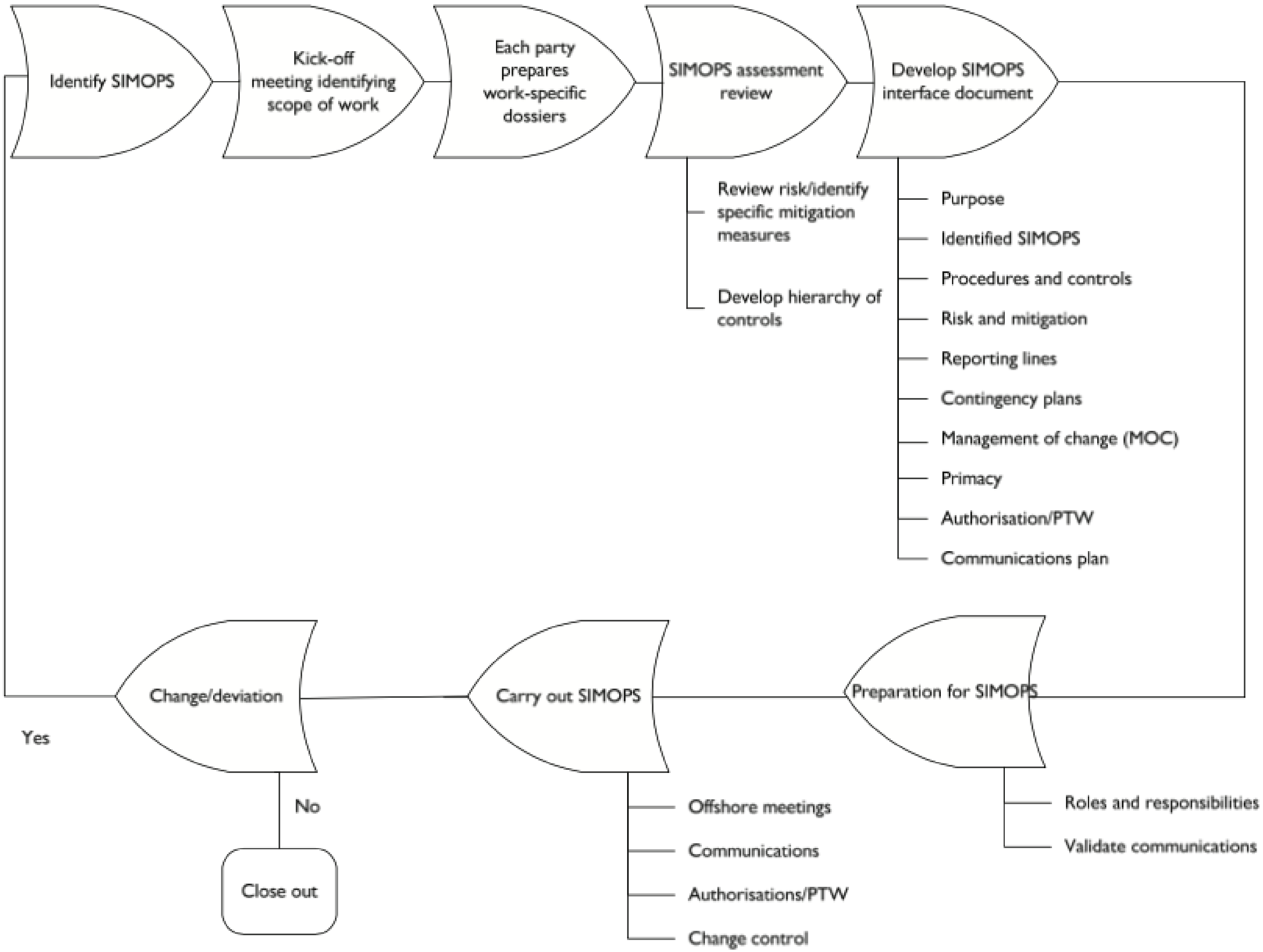


Figure 63 - SimOps flow diagram

Of particular use to the DP vessel crew, deck and engineering officers is the section 4.7 of that document that emphasises the role of communications between interested parties including the PIC, the person-in-charge or controlling authority or entity directing field operations.

- *Once the SIMOPS has started, it is important that there is regular communication between all involved parties.*
- *Daily Meetings During the whole duration of the SIMOPS work, a daily conference call (or meeting if feasible) should be held between the representatives of the involved parties to review the progress of the current SIMOPS activity and to organise the planning and safety of the remaining work.*
- *Regular Communications During the SIMOPS the communications plan identified in the SIMOPS interface document should be followed. Regular checks should be made and documented between vessels in the 500m zone. During certain critical activities it may be desirable to initiate continuous, real-time communications, either two-way or by one vessel describing the operation and the others listening. The communications plan should have identified the preferred means of continuous communications to ensure that important information is received and directed to the appropriate person or PIC*

Mission Specific Operations
General Considerations
Introduction to different mission types & available guidance
The mission - its interaction with DP redundancy concept (load limitation priorities, sharing of common supplies (e.g., power, cooling, ventilation), DP3 F&F integrity of mission equipment, draught changes (e.g. heavy lifts), wind profile, blocking of PRS signals
Reference systems & Sensors (general considerations from a mission perspective)
Operational planning (general considerations from a mission perspective)
Dive Support Vessels
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission Operational Considerations & Planning - specific to mission
Pipe Lay/Cable Lay
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
ROV Support
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
Heavy Lift
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission
Operational Considerations & Planning - specific to mission
Float Over
General description / considerations - specific to mission
Reference Systems & Sensors - specific to mission

INTRODUCTION TO DIFFERENT MISSION TYPES & AVAILABLE GUIDANCE

MTS DYNAMIC POSITIONING COMMITTEE

See also MTS DP committee

MTS DP Operations Guidance - Part 1 states that The DP vessel should be equipped with suitable DP Modes [See **DP Modes of operation**] and features with due consideration to **operational requirements, both with regard to restrictions caused by the activity and performance criteria required to execute the activity safely and successfully**.

4.7.2 The following selected DP control modes are relevant to specific DP activities.

- *Target Follow Enables the DP vessel to follow a moving target and is used, for example, to follow an ROV along a pipeline.*
- *Heavy Lift Takes account of the effects of the load transfer on the mass of the vessel and the additional lateral force, normally by reducing gain and relaxing the DP controller.*

4.7.3 External Force Compensation - Where the measured external force acting on the vessel, which is separate from the environment, is included in the DP calculation and treated as a force feed forward. This mode is used to account for pipe tensions in a pipe layer and hawser tension in a shuttle tanker.

4.7.4 Fire Monitor Compensation - Used to compensate for the varying forces exerted on vessel from the fire monitors.

Weathervane: Enables the DP vessel to rotate with the wind, current and waves around a fixed or moving point called the terminal point. Neither the heading nor the position of the DP vessel is fixed. The heading of the vessel is controlled to point towards the terminal point. The position of the vessel is controlled to follow a circle, called the setpoint circle, around the terminal point. This mode is appropriate for connected shuttle tanker/ FPSO operations.

Caution: It is not uncommon for the term "weathervane" to be used to denote "minimum thrust", i.e. where the DP control system allows the vessel's heading to rotate to minimize external forces acting on the vessel and thruster requirements. These terms should not be confused.

There have been incidents where inappropriate modes have been used to perform operations. For example, a moving vessel where the DP was in fixed position mode using 2 x DGPS and a laser. The DPO monitored the laser (which was measuring the distance to the other vessel) and when it changed the DPO would reset the fixed position to match laser. This was not appropriate and clearly does not meet DP2 as the DP is totally reliant on the two DGPS as the laser was polluting the DP model position as the DP was assuming it was a fixed target and hence was indicating motion of the DP vessel rather than the target vessel. The ASOG (had there been one) would not have been able to endorse these kind of actions.

MTS have written three documents that apply to vessels engaged in the industrial missions of mobile offshore drilling (MODUs), project construction, and logistics vessels.

DP Operations Guidance - Part 2 - Appendix 1 - MODUs

DP Operations Guidance - Part 2 - Appendix 2 - Project Construction Vessels

DP Operations Guidance - Part 2 - Appendix 3 - Logistics Vessels

IMCA

See also IMCA

IMCA M 130. There are eighteen different types of DP vessels listed in IMCA M103with sections on:

- Industrial Mission
- Description and Role
- Design Guidance
- Design Considerations
- DP Capability
- Control Systems
- Reference Systems and Sensors
- Power Systems
- Operational Guidance
- Operational Considerations
- Communications
- DP Alert Status
- Gangway Status
- Responsibilities

We recommend that you access IMCA M103before you begin the following sections of this Learning Manual.

- IMCA have issued the following documents in addition to IMCA M103 which will be explored later in this section.
- IMCA D 010 Diving operations from vessels operating in dynamically positioned mode
- MCA D 039 FMEA guide for diving systems
- IMCA D 054/IMCA R 020 Remotely operated vehicle intervention during diving operations
- IMCA M 125 Safety interface document for a DP vessel working near an offshore platform
- IMCA M 159 Guidance on thruster-assisted station keeping by FPSOs and similar turret-moored vessels
- IMCA M 223 Guidance for the positioning of dynamically positioned (DP) jack-up vessels on and off the seabed

MARINE SAFETY FORUM

See also Marine Safety Forum

182 MSF International guidelines for the safe operation of dynamically positioned offshore supply vessels

Tandem Loading Guidelines Volume 2 The Use of Towing Assistance for F(P)SO and Shuttle Tanker Operations

OCIMF

The Oil Companies International Marine Forum (OCIMF) was formed in response to the growing public concern about marine pollution. OCIMF claim to be a leading authority on safety for the global marine industry, has over 100 member companies, and consultancy status at the IMO.

Their mission is to lead the global marine industry in the promotion of safe and environmentally responsible transportation of crude oil, oil products, petrochemicals and gas, and to drive the same values in the management of related offshore marine operations. We do this by developing best practices in the design, construction and safe operation of tankers, barges and **offshore vessels** and their interfaces with terminals.

Guidelines for Offshore Tanker Operations' (GOTO) First Edition 2018

Competence Assurance Guidelines for F(P)SOs 1st Edition

F(P)SO Heading Control Guidelines 2 November 2020

THE MISSION - ITS INTERACTION WITH DP REDUNDANCY CONCEPT

Load limitation priorities, sharing of common supplies (e.g. power, cooling, ventilation), DP3 Fire and Flood (F&F) integrity of mission equipment, draught changes (e.g. heavy lifts), wind profile, blocking of PRS signals

The industrial mission of a dynamically positioned vessel can have a significant impact on the redundancy concept of the vessel's systems and equipment.

Each mission type as identified in ICMA M103are discussed below. We recommend you read IMCA M103 in full.

See also Power and Position References and Sensors, and reference systems & sensors (general considerations from a mission perspective) and Operational Planning and Decision Support Tools

See also DP Position Reference Systems and Sensors

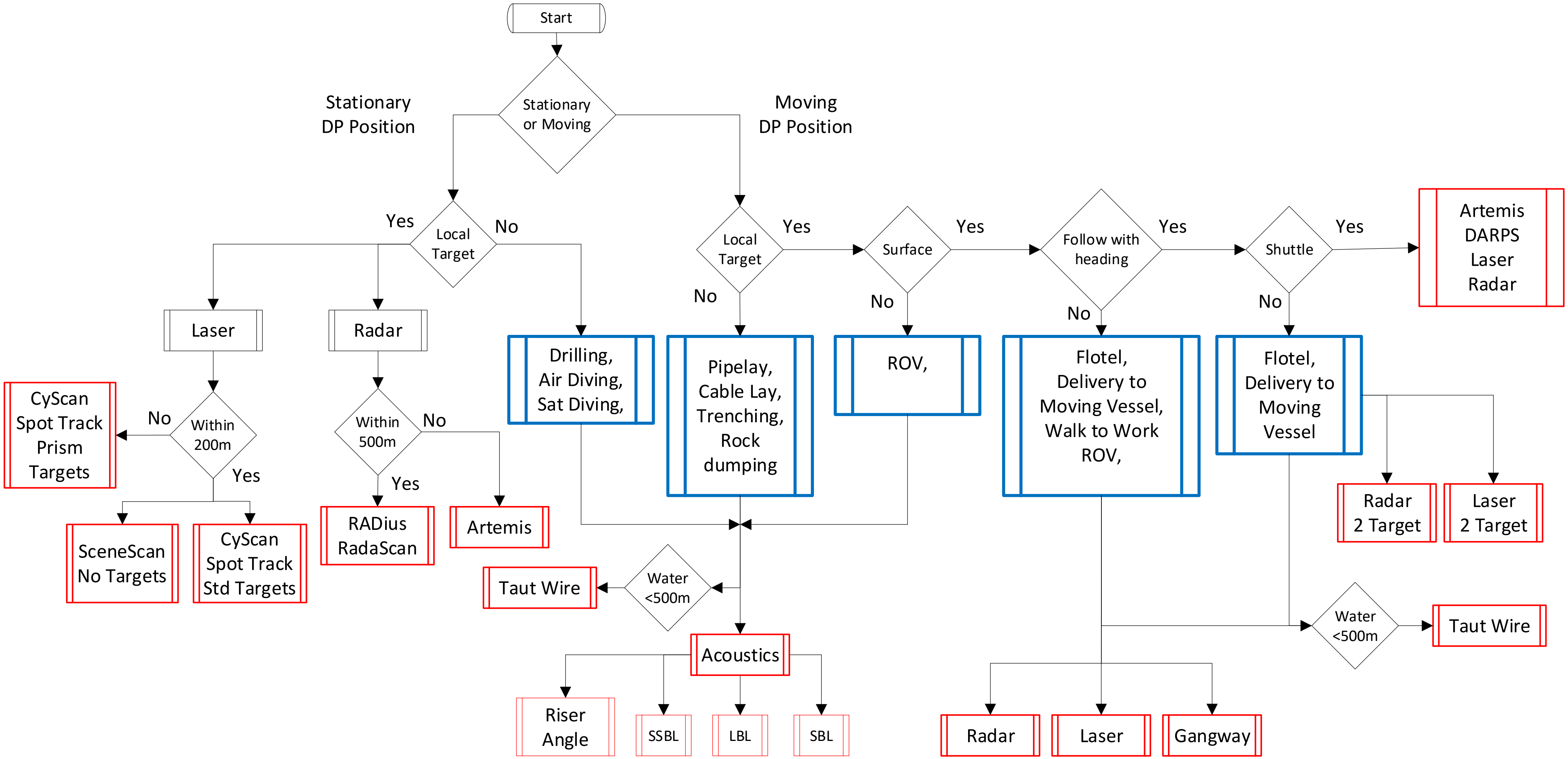


FIGURE 64 - DECISION TREE FOR APPROPRIATE POSITION REFERENCE SOLUTIONS

MTS have written three documents that apply to vessels engaged in the industrial missions of mobile offshore drilling (MODUs), project construction, and logistics vessels.

DP Operations Guidance - Part 2 - Appendix 1 - MODUs

DP Operations Guidance - Part 2 - Appendix 2 - Project Construction Vessels

DP Operations Guidance - Part 2 - Appendix 3 - Logistics Vessels

In these documents tables and supporting notes are provided to help position reference choices. This data is provided in this learning material in the Position Reference Systems and Sensors chapter.

See also Operational Planning and Decision Support Tools

MTS DP Operations Guidance - Part 1

4.10 ACTIVITY OPERATIONAL PLANNING

4.10.1 In recognizing that exposure to risks manifests itself during vessel operations it is recommended that activities performed by DP vessels should be subject to planning and preparation. In planning and preparing for the activities the following should be considered and, where appropriate, documented:

- *Configuration for the Critical Activity Mode of Operation (CAMO) or, where appropriate, the Task Appropriate Mode (TAM).*
- *Preparation of the Activity Specific Operating Guidelines (ASOG), including onboard discussion with all relevant stakeholders as part of the pre-project execution/ activity.*
- *Discussion to be included in pre-project execution readiness checklist.*
- *Capabilities of the vessel, both intact and residual capability, following Worst Case Failure (WCF).*
- *Limitations imposed by water depth.*
- *Consequences of a loss of position and/ or heading.*
- *Limitations imposed upon operations by residual capability.*
- *SIMOPS and marine vessel interaction and consequences arising from change of status (Green to Blue, Yellow or Red).*
- *The activity being performed and the necessary time to terminate to bring vessel to a safe position upon the onset of failure.*

4.10.2 Activities should include day to day operations, any specific operation relevant to the design of the vessel, as well as any unique operations the vessel is called upon to perform.

4.10.3 Appropriate measures should be in place to clearly identify critical tasks/ operational phases of the activity and to ensure that the vessel is set up in Critical Activity Mode of Operation and operating within post WCF capability. Where a decision has been made to operate in a TAM a separate ASOG covering TAM should be produced.

Note: The ASOG should be developed by extracting all the relevant information from detailed technical review of the vessel's DP FMEA, operational manuals and project specific procedures. The ASOG should be validated on board.

4.10.4 On a DP MODU, ASOGs are known as WSOGs. Some owners refer to it as WSOC (Well Specific Operating Criteria)

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

A dive support vessel is a vessel specifically designed and equipped to support underwater diving operations, such as scientific research, commercial diving, or search and rescue missions. It typically features equipment for diving, such as compressors, air tanks, diving bells, and cranes for launching and recovering divers. It may also have additional features for safety, such as medical facilities, emergency evacuation equipment, and communication systems. The vessel may be used as a platform for divers to enter and exit the water, as well as a base of operations for dive teams to plan and coordinate their activities.

Diving falls into 2 main categories. First, air diving where the divers may enter the water from a basket over the side of the vessel and due to the limited depth for air diving tend to be closer to the vessel. Secondly is saturated diving where the divers can go to greater depth, breathe mixed gas and are kept under operational pressure for the duration of the operation. They will work from a ‘bell’ that would normally be positioned close to the sea bed, but becomes a hazard if the DP vessel drifts or drives off position.

DP vessels offer several hazards to divers including:

Propeller strikes: Divers may be at risk of being struck by the vessel's propellers (normally the use of tethers should ensure sufficient distance is maintained)

Turbulence and waves: The operation of the thrusters can generate significant turbulence and waves in the surrounding water, making it more difficult for divers to maintain their position and stability.

Debris: The thrusters can create a discharge of debris, including mud, sand, and rocks, which can pose a hazard to divers who are in the water.

Noise: The operation of the thrusters can generate significant noise levels, which can be harmful to divers' hearing and affect their ability to communicate with the dive team.

Reduced visibility: The operation of the thrusters can create a cloud of sediment or bubbles in the water, reducing visibility and making it more difficult for divers to navigate and carry out their tasks.

However, the most critical hazard would be a DP failure that results in a loss of position. In the event of a DP failure, the vessel may not be able to safely evacuate divers who are in the water, increasing the risk of injury or death.

IMCA M103offers a whole section on the *A1-1 Industrial Mission* of ***Diving Support Vessels.*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A1-1 Industrial Mission
- A1-1.1 Description and Role
- A1-2 Design Guidance
- A1-2.1 Design Considerations
- A1-2.2 DP Capability
- A1-2.3 Control Systems
- A1-2.4 Reference Systems and Sensors
- A8-2.5 Power Systems
- A1-3.1 Operational Guidance
- A1-3.2 Operational Considerations
- A1-3.3 Communications
- A1-3.4 DP Alert Status
- A1-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS	DGNSS
Acoustics (USBL)	Acoustics (USBL)
Tautwire	Tautwire
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for dive support vessels and must be read in conjunction with IMCA M103 in its entirety.

A1-2.4 Reference Systems and Sensors

At least three independent position reference systems and three independent heading reference sensors should be in use for diving operations.

Both surface and seabed referenced systems should be fitted providing a combination of both absolute and relative references.

At least two different measurement principles should be employed for the position reference systems at any time; three principles should be employed whenever possible. When operating close to a surface structure then at least one relative reference should be in use.

Power for the position references should be supplied from different redundancy groups to prevent the worst case single failure resulting in the loss of all position references.

Position reference systems should be resistant to interference from diving operations.

Hull transducers and seabed transponders used for acoustic systems should be positioned to minimise possible attenuation caused by bubbles in the water column.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA D -101 Rev. 2 – July 2000 as its name suggests is used by the diving division of IMCA, rather than the marine committee and contains some technical details for divers and tier superintendents. However it also contains the following for vessel's master and DPOs.

Vessel masters

The master of a vessel is ultimately responsible for the safety of the vessel and all personnel working on or from it. ***He can veto the start, or order the termination, of a diving operation through the diving supervisor.***

DP operators

The DP operator (dynamic positioning control system operator) in charge of the DP system must be suitably trained and experienced. ***The DP operator is responsible for the station-keeping of the vessel****, and must keep the other relevant control centres of the vessel informed of changes in operational conditions and circumstances, e.g. dive control).*

Section 4.2 discusses the possible improvement of diver's safety by deselecting thrusters.

Isolation of thrusters or propellers

The feasibility of improving operational safety by deselecting or isolating relevant thrusters or propellers should be considered as part of the risk assessment. This can only be decided by the vessel master. If this is considered to be a viable procedure, the work scope should take account of the reduced capability, and arrangements should be made to ensure that thruster units and/or propellers, which have been isolated or stopped, remain stopped and isolated whenever divers are in the water.

And section 6 discusses vessel movement while the divers are deployed.

6 VESSEL MOVEMENT LIMITATIONS

A diving support vessel under stable DP control may execute changes to a previously agreed position or heading without recalling the divers to the deployment device, provided all relevant personnel have been advised, and that the DP operator and the diving supervisor are both satisfied with the following criteria:

- *the move can be executed safely*
- *umbilical's and other diving-related work lines (see Section 7.2) are clear and will remain so during the move*
- *divers understand the move and are not endangered by it*
- *divers can easily reach the deployment device*
- *three position references will be on-line throughout the move*
- *the move is executed at low speed*
- *change of heading and position are not carried out simultaneously*
- *the move can be stopped at any time*
- *the move will not exceed the scope of any one of the three position references*
- *the move will be stopped if one position reference has to be repositioned and this results in only two position reference systems being on-line*
- *the DP operator will verify the move input before execution*
- *due account has been taken of the selected centre of rotation when heading is to be changed.*

If the DP operator has any doubts about the safety of the move, he should instruct the diving supervisor to recall the divers to the deployment device and stop the move to reassess the safety of proceeding.

IMCA M103 offers the following operational considerations for dive support vessels and must be read in conjunction with IMCA M103 in its entirety.

IMCA M103A1-3.1 Operational Considerations

For additional information please refer to IMCA D 010 – Diving operations from vessels operating in dynamically positioned mode. The following should be considered:

- *The time to terminate for diving operations, this is influenced by dive depth, environmental conditions and nature of diver's worksite;*
- *The power plant and thrusters are to be suitably configured prior to commencing diving operations;*
- *The most robust fault-tolerant switchboard configuration is most likely to be achieved by operating in open bus tie mode. The switchboard may be configured with closed bus ties provided that the FMEA and a thorough analysis have demonstrated that this provides an equivalent degree of fault tolerance to open bus tie mode;*
- *The integrity of seabed position references may be affected by diver activity;*
- *These reference systems (including associated clump weights) should be managed by the DPO in close co-operation with the diving supervisor to ensure that sufficient reference redundancy is maintained and that risk to divers and subsea infrastructure is minimised;*
- *The proximity of diver deployment and recovery devices to subsea hazards should be considered; vessel drift-off direction should be verified if there are risks of fouling umbilical's and deployment systems. Diver*

deployment devices should be positioned above the level of potential underwater obstructions where practicable;

- *Environmental limits for the diving operations may be governed by the heave limits of deployment devices rather than by the vessel's ability to maintain position;*
- *The DPO should be provided with information identifying all secured down-lines and subsea lifts by the diving supervisor;*
- *Resetting or repositioning position reference systems during a dive should be avoided, however this may be permitted if it is not carried out simultaneously with a vessel change of heading or position and where it can be completed quickly and safely. Station keeping should be stable prior to deselecting the reference from DP;*
- *Seabed acoustic devices utilised by the DP system may only be moved by divers with the direct permission of the DPO and under the supervision of the diving supervisor;*
- *Relative position reference systems for the DP control system should only be used when the remote reference point is static. Are lative system reference point may be fitted on a floating structure where minimal movement has been verified. Non-fixed reference points may be used to monitor and alert the DPO of movement of adjacent floating structures where the reference is not part of the DP system;*
- *In determining safe separation limits between the DP diving vessel and an adjacent fixed structure, the following is recommended:*
  - *i) the vessel position footprint under normal operating conditions should not exceed 50% of a defined critical excursion limit*
  - *ii) the critical position excursion limit should not exceed 50% of the separation distance between the vessel and adjacent structure*
  - *iii) minimum separation between any point of the DP diving vessel and the adjacent structure should normally not be less than 10m.*

IMCA M103 offers the following operational planning for dive support vessels and must be read in conjunction with IMCA M103 in its entirety.

A1-3.2 Operational Planning

Where appropriate the following should be documented:

- *Risk assessment for the loss of vessel position at all stages of the diving operation;*
- *Assessment of the potential drift-off rate and direction, in conjunction with an assessment of the time to terminate (time necessary to recover divers to a position above adjacent subsea obstructions);*
- *Configuration of DP related systems for the critical activity mode of operation (CAM);*
- *Activity specific operating guidelines (ASOG) to provide a decision support tool for the DPO in the event of loss of DP critical systems, and the procedures necessary to safely recover divers to the vessel;*
- *Permission to dive – to include the conduct of specific DP system checks, the obtaining of approval/permits from relevant personnel and the exchange of necessary information between vessel control positions and adjacent installation (if applicable);*
- *An operations plot at the DP and dive control positions displaying the relative positions of the vessel, the diver's deployment device, diver's work site, and any known obstructions;*
- *Diver umbilical length diagrams where a risk exists of divers or their umbilical's coming into contact with vessel thrusters. Umbilical lengths for the divers should prevent approach within 5m of the nearest thruster. The*

standby diver umbilical length should prevent approach closer than 3m to the nearest thruster so as to facilitate rescue of divers if required.

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

A pipe laying vessel is a ship that is designed and equipped for installing underwater pipelines. It typically has a specialized derrick or crane system for handling and laying large sections of pipeline, as well as other equipment for handling and welding the pipes together. The ship also has accommodation and support facilities for the crew and technicians.

The three types of pipe laying systems commonly used are:

1. S-Lay pipe laying operations involve laying pipeline sections in a curved or S-shaped pattern from the stern of the vessel. The pipe is held under tension by tensioners and is gradually lowered into the water and placed on the seabed. This method is well suited for deep water installations and is capable of laying large diameter pipes.

   The following steps summarize the S-Lay process:

   - Loading: The pipes are loaded onto the vessel and positioned at the stern.
   - Welding: The pipes are welded together to form a continuous pipeline.
   - Tensioning: Tensioners are used to apply tension to the pipeline to control its curvature.
   - Laying: The pipeline is gradually lowered into the water and placed on the seabed.
   - Backfilling: The gap between the pipe and seabed is backfilled with material to provide stability and support.
   - Burial: The pipeline is buried to protect it from damage caused by fishing or anchor dragging.

   The S-Lay system is a flexible and efficient method of installing pipelines in deep waters, but it requires a specialized vessel with a large deck area and a specialized crane system for handling the pipes.

2. J -Lay pipe laying operations involve laying pipeline sections vertically from the bow or stern of the vessel, using a tower or derrick structure. This method is well suited for laying large diameter pipes and is capable of handling heavy pipe sections.

   The following steps summarize the J-Lay process:

- Loading: The pipes are loaded onto the vessel and positioned near the tower.
- Welding: The pipes are welded together to form a continuous pipeline.
- Lifting: The pipeline is lifted vertically by the tower and positioned over the seabed.
- Lowering: The pipeline is gradually lowered into the water and placed on the seabed.
- Backfilling: The gap between the pipe and seabed is backfilled with material to provide stability and support.
- Burial: The pipeline is buried to protect it from damage caused by fishing or anchor dragging.

The J-Lay system is a flexible and efficient method of installing pipelines in deep waters, but it requires a specialized vessel with a large deck area and a specialized tower or derrick system for handling the pipes. It also requires a relatively stable seabed for accurate placement of the pipeline.

3. Reel-Lay pipe laying operations involve winding the pipeline sections onto a large storage reel on the vessel and deploying it from the vessel in a controlled manner. This method is well suited for shallow water installations and for laying pipelines in areas with limited seabed access.

   The following steps summarize the Reel-Lay process:

- Loading: The pipes are loaded onto the vessel and positioned on the storage reel.
- Welding: The pipes are welded together to form a continuous pipeline.
- Winding: The pipeline is wound onto the storage reel, ready for deployment.
- Deployment: The pipeline is deployed from the reel and placed on the seabed.
- Backfilling: The gap between the pipe and seabed is backfilled with material to provide stability and support.

- Burial: The pipeline is buried to protect it from damage caused by fishing or anchor dragging.

The Reel-Lay system is a flexible and efficient method of installing pipelines in shallow waters and in areas with limited seabed access, but it requires a specialized vessel with a large deck area and a specialized reel system for handling the pipes. The reel-lay method also limits the maximum size and length of the pipeline that can be installed.

Each type of system has its own advantages and disadvantages, and the choice of system depends on the specific project requirements, such as the depth of the water, the length and size of the pipeline, and the environmental conditions.

A cable lay vessel is a specialized ship used for laying and burying underwater communication or power cables. It is equipped with machinery and tools for handling, deploying, and burying the cables, including a winch system, a plow or jetting system, and storage reels. The vessel may also have facilities for splicing and repairing the cables, as well as accommodation and support systems for the crew.

- The cable lay process involves laying underwater communication or power cables from a cable lay vessel. The following steps summarize the cable lay process:
- Loading: The cable is loaded onto the vessel and positioned on the storage reel.
- Splicing: The cable is spliced together to form a continuous cable, if necessary.
- Winding: The cable is wound onto the storage reel, ready for deployment.
- Deployment: The cable is deployed from the vessel and placed on the seabed.
- Bury: The cable is buried to protect it from damage caused by fishing or anchor dragging.
- Monitoring: The cable is monitored during and after deployment to ensure it is laid correctly and to detect any faults.
- Repair: If necessary, the cable is repaired using specialized equipment carried on the cable lay vessel.

The cable lay process requires specialized equipment and trained personnel, as well as careful planning and coordination to ensure the cable is laid correctly and without damage. The depth of the water, the length and size of the cable, and the environmental conditions can all affect the cable lay process.

Tension in the cable can add an additional external force to the DP system that the DPO must be aware of. Additionally, sea floor topography can affect the position of the cable and the vessel, particularly in shallow water or areas with irregular seabed and add an additional external force to the DP system.

IMCA M103offers a whole section on the *A1-1 Industrial Mission* of ***Pipelay Vessels.*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A2-1 Industrial Mission
- A2-1.1 Description and Role
- A2-2 Design Guidance
- A2-2.1 Design Considerations
- A2-2.2 DP Capability
- A2-2.3 Control Systems
- A2-2.4 Reference Systems and Sensors
- A2-2.5 Power Systems
- A2-3.1 Operational Guidance
- A2-3.2 Operational Considerations
- A2-3.3 Communications
- A2-3.4 DP Alert Status
- A2-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	DGNSS (Inertial)
Acoustics (inertial) LBL & USBL	Acoustics (inertial) LBL & USBL
Tautwire (<400m)	Tautwire (<400)
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for pipe lay vessels and must be read in conjunction with IMCA M103 in its entirety.

A2-2.4 Reference Systems and Sensors

At least three independent position reference systems and three independent heading reference sensors should be in use for critical pipelay operations.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

In shallow water, or when working in close proximity to offshore installations, at least two different measurement principles should be employed for the reference systems.

In deep water and open water locations there may be a reliance on satellite based position references, satellite based systems should be sourced from different manufacturers to avoid software induced common cause failures. Independence should be provided by the separation of power supplies. Different methods for differential corrections should be employed. No single failure should result in the loss of more than one position reference system. Consideration should be given to using position reference systems in combination with inertial navigation systems to filter short term instability.

When engaged in cargo operations with another vessel operating on DP, relative position reference systems should only be used by one vessel where the other is the fixed reference.

A pipe tension sensor may be interfaced to the DP control system; in such cases it is essential that the tension input is accurate, has redundancy and is reliable. This also applies to any winch used to assist particular operations such as pipeline pull in. Where redundancy or fail safe cannot be demonstrated then manual input of pipe tension may be permissible.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational planning for pipe lay vessels and must be read in conjunction with IMCA M103 in its entirety.

A2-3.1 Operational Considerations

The following should be considered when planning DP pipelay operations:

- *Depending on the pipelaying mode utilised there may be a long time to terminate operations. Flexible pipes and umbilical's cannot be terminated midway through the lay operation without significant damage occurring to the product through cutting, however rigid pipes can be terminated at any point with the product end being capped and lowered to the seabed;*
- *If pipe tension and catenary are not maintained then damage to the product, pipelay equipment and injury to personnel may occur;*
- *Rapid changes in pipe tension may cause instability in position if not accurately modelled in the DP system;*
- *Significant propulsion power may be required to maintain a horizontal component of pipe tension; this may reduce the position keeping capability in response to environmental forces;*
- *Availability and diversity of position references may be limited in open water and deep water;*
- *The pipelay activity may restrict choice of heading;*
- *Initiation and completion activities may be subject to more strict environmental and vessel motion limits than those for lay activities;*
- *The master and each DPO should be aware of the required tensions used for pipelay operations and the appropriate emergency responses;*
- *The pipelay supervisor should have instruction in the basic operation of the dynamic positioning system and the capabilities of the vessel in order to understand the potential vessel responses to requests for changes in position.*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

A Remotely Operated Vehicle (ROV) vessel is a maritime vessel equipped with underwater drones (ROVs) used for various subsea operations. The following steps summarize the operations of an ROV vessel:

1. Loading: The ROV and associated equipment are loaded onto the vessel.
2. Deployment: The ROV is deployed into the water and remotely controlled from the vessel.
3. Surveying: The ROV is used to survey the underwater environment, including the seabed, pipelines, and subsea infrastructure.
4. Inspection: The ROV is used to inspect subsea structures and equipment for damage or wear.
5. Maintenance: The ROV is used to perform maintenance and repair work on subsea structures and equipment.
6. Data collection: The ROV is used to collect data and samples from the underwater environment.
7. Recovery: The ROV is recovered onto the vessel after the mission is completed.

ROV vessels are equipped with specialized systems and equipment to support ROV operations, including launch and recovery systems, control systems, and data communication systems. The ROVs themselves are equipped with various tools, cameras, and sensors to support their mission. ROV vessels are used in a wide range of subsea operations, from surveying and inspection to maintenance and repair, and play an important role in the offshore oil and gas industry, as well as in scientific research and environmental monitoring.

IMCA M103offers a whole section on the *A1-1 Industrial Mission* of ***ROV Support Vessels.*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A3-1 Industrial Mission
- A3-1.1 Description and Role
- A3-2 Design Guidance
- A3-2.1 Design Considerations
- A3-2.2 DP Capability
- A3-2.3 Control Systems
- A3-2.4 Reference Systems and Sensors
- A3-2.5 Power Systems
- A3-3.1 Operational Guidance
- A3-3.2 Operational Considerations
- A3-3.3 Communications
- A3-3.4 DP Alert Status
- A3-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	DGNSS (Inertial)
Acoustics (inertial) LBL & USBL	Acoustics (inertial) LBL & USBL
Tautwire (<400m)	Tautwire (<400)
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for ROV support vessels and must be read in conjunction with IMCA M103 in its entirety.

A3-2.4 Reference Systems and Sensors

At least three independent position reference systems should be in use for critical activities where fault-tolerant operation is required.

When working in close proximity to surface structures at least two different measurement principles should be employed for reference systems, one of which should be a relative position reference system.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational considerations for ROV vessels and must be read in conjunction with IMCA M103 in its entirety.

A3-3.1 Operational Considerations

The following should be considered when planning DP ROV operations:

- *ROV operations usually have a short time to terminate; providing there are no adjacent structures then loss of DP control may not have serious consequences for the vessel. Recovery of the ROV to surface may be protracted but should not be prevented by an inability to maintain position;*
- *In low risk operating conditions the DP system need not be configured to be fault-tolerant (TAM);*
- *Availability and diversity of position reference systems may be limited in open water and in relative location DP operations;*
- *Acoustic position reference systems are frequently used for tracking mobile ROV beacons, potential interference with DP position references should be minimised when using such systems. ROV beacons should be operated in responder mode where practicable;*
- *There may be a reliance on satellite based position references when in deep and/or open water where the risks associated with an inability to maintain position are low, this should be documented in the CAM/TAM;*
- *Use of the ROV beacon as a 'fixed' position reference to facilitate a constant offset between vessel and ROV should be avoided as this configuration necessitates the use of a single DP reference and may result in high propulsion power demand if the speed or direction of travel of the ROV changes rapidly;*

- *Use of the ROV beacon as a 'fixed' position reference may be permissible when other references have failed and when the ROV has been instructed to fix its position through attachment to a seabed structure, or by setting down on the seabed;*
- *ROV launch and recovery operations may be subject to tighter environmental and vessel motion limits than during the ROV dive;*
- *It is generally acceptable for the vessel to adopt a heading which minimises vessel motion and/or thruster loads unless proximity to surface structures or the needs of ROV launch/ recovery operations dictate otherwise.*

CRANE VESSELS (NOT REQUIRED BY THE NAUTICAL INSITUTE BUT IN IMCA M 103)

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

The primary operational role of the vessel is lifting offshore structures, including installation and subsequent decommissioning of offshore structures and modules.

DP crane vessels may be monohull or semi-submersible vessels provided with large capacity cranes or derricks.

Crane vessels may either transport the items intended for lifting or transfer the lift offshore between a transport vessel/barge and the installation location.

Large capacity crane vessels predominantly operate with the lifting hook above sea level or in shallow immersion due to the limited length of lifting wires and the effects of sea water on blocks and wires. Largemassstructuresforsubmergedseabedinstallationaregenerallyinstalledbymeans of buoyancy lift.

Heavy lift crane operations are sensitive to wind speed and sea state.

Crane vessels may be either pure crane vessels or multi-purpose vessels, alternative functions may be operable in environmental conditions which would preclude lifting operations.

A motion compensated gangway may be provided to facilitate personnel transfer between the crane vessel and the installation/decommissioning site.

The ballast arrangements of crane vessels are to be capable of ensuring adequate stability and controlling trim and heel at all times during lifting.

Lifting operations are conducted in close proximity to other vessels or offshore structures and tugs and barges may be required to manoeuvre under the crane hook. Crane vessels regularly operate in close proximity to offshore structures when lifting.

The consequences of loss of vessel position may include injury to personnel, damage to the suspended load and to the adjacent offshore installation or support vessels, damage to the crane vessel and environmental pollution.

IMC M103offers a whole section on the *A6-1 Industrial Mission* of ***Service Operations Vessels (SOV).*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A4-1 Industrial Mission
- A4-1.1 Description and Role
- A4-2 Design Guidance
- A4-2.1 Design Considerations
- A4-2.2 DP Capability
- A4-2.3 Control Systems
- A4-2.4 Reference Systems and Sensors
- A4-2.5 Power Systems
- A4-3.1 Operational Guidance
- A4-3.2 Operational Considerations
- A4-3.3 Communications
- A4-3.4 DP Alert Status
- A4-3.5 Gangway Status
- A4-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	DGNSS (Inertial)
Relative GNSS	Relative GNSS
Acoustics (inertial) LBL & USBL	Acoustics (inertial) LBL & USBL
Tautwire (<400m)	Tautwire (<400)
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for crane vessels and must be read in conjunction with IMCA M103 in its entirety.

> *A4-2.4 Reference Systems and Sensors*
>
> *At least three independent position reference systems using a minimum of two measurement principles should be in use during lifting operations or when in close proximity to another vessel or structure.*
>
> *At least three independent heading reference sensors for the DP system should be provided.*
>
> *When working in close proximity to fixed structures then at least one relative position reference system should be used. If the adjacent structure is floating and a relative separation needs to be maintained then at least two of the position references used should be relative systems.*
>
> *Reference systems should be selected so as to minimise possible degradation during load transfer, changes in draught and changes in position of the suspended load.*
>
> *Power for position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.*
>
> *When the vessel is manoeuvring clear of other vessels or structures then a minimum of two position reference systems should be in use with a third immediately available.*
>
> *At least three independent wind sensors should be provided, positioned to allow for local disruption of wind flow caused by crane and lift position, information should be corrected to a common height at the DP control station.*

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational considerations for crane vessels and must be read in conjunction with IMCA M103 in its entirety.

> *A4-3.1 Operational Considerations*
>
> *The following should be considered when planning DP operations:*

- *Lifting operations prior to connection of rigging may be characterised by a short to medium time to terminate. Once rigging has been connected or lifting commenced there may be no possibility to safely terminate the lift before actual completion of the operation. This should be identified during operational planning and the duration of such activities minimised;*

- *Position instability may occur during periods of rapid load transfer;*

- *Lifting operations are subject to wind and wave limits. Wind forces may be high due to the size and shape of the vessel structure and lift, and may vary significantly depending on the position of the cranes;*

- *The risk that radar or laser range-finding position reference instruments may have the line of sight with their target obstructed by the lift should be analysed and mitigated;*

- *The risk that the signal from satellite derived position reference systems may be affected by the movement of the crane jib and or load should be analysed and mitigated;*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

Heavy lift vessels play a crucial role in the offshore oil and gas industry, as well as in the construction and installation of offshore platforms, wind turbines, and subsea pipelines. To ensure safe and successful operations, heavy lift vessels are equipped with a range of systems and equipment, including dynamic positioning systems, load monitoring systems, and navigation and communication systems.

The following steps summarize the operations of a heavy lift vessel:

1. Loading: The heavy structure is loaded onto the vessel using cranes or other specialized equipment.
2. Transport: The vessel transports the heavy structure to the installation site.
3. Positioning: The vessel uses dynamic positioning systems to maintain its position over the installation site.
4. Installation: The heavy structure is installed using the vessel's cranes or other specialized equipment.
5. Ballasting: The vessel may adjust its ballast to ensure stability during the installation process.
6. Securing: The heavy structure is secured in place using mooring systems or other specialized equipment.
7. Completion: The installation process is completed and the vessel departs the site.

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	DGNSS (Inertial)
Relative GNSS	Relative GNSS
Acoustics (inertial) USBL	Acoustics (inertial) USBL
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for heavy lift vessels and must be read in conjunction with IMCA M103 in its entirety.

A4-2.4 Reference Systems and Sensors

At least three independent position reference systems using a minimum of two measurement principles should be in use during lifting operations or when in close proximity to another vessel or structure.

At least three independent heading reference sensors for the DP system should be provided.

When working in close proximity to fixed structures then at least one relative position reference system should be used. If the adjacent structure is floating and a relative separation needs to be maintained then at least two of the position references used should be relative systems.

Reference systems should be selected so as to minimise possible degradation during load transfer, changes in draught and changes in position of the suspended load.

Power for position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

When the vessel is manoeuvring clear of other vessels or structures then a minimum of two position reference systems should be in use with a third immediately available.

At least three independent wind sensors should be provided, positioned to allow for local disruption of wind flow caused by crane and lift position, information should be corrected to a common height at the DP control station.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational considerations for heavy lift vessels and must be read in conjunction with IMCA M103 in its entirety.

A5-3.1 Operational Considerations

The following should be considered when planning DP operations:

- *Float-over operations prior to mating and commencement of load transfer may be characterised by a short time to terminate. Once load transfer has commenced there may be no possibility to safely terminate the float-over before actual completion of the operation. This should be identified during operational planning and the duration of such activities minimised;*
- *Position instability may occur during periods of rapid load transfer;*
- *Due to the critical nature of vertical motion, consideration should be given to the detection*
- *of possible movements of fresh water (freshets) that could cause draught to change;*
- *The minimum float-over clearance will be determined based on vessel draught, environmental conditions and maximum motion amplitudes at the mating points;*
- *Where fenders are fitted to distribute contact load the effects of moderate horizontal forces experienced through such contact loads should be anticipated;*
- *Lifting operations are subject to wind and wave limits. Wind forces may be high due to the size and shape of the load, and may vary significantly depending on the position of vessel equipment such as cranes;*
- *The risk that radar or laser range-finding position reference instruments may have the line of sight with their target obstructed by the lift should be analysed and mitigated;*
- *A vessel emergency escape route should always be planned.*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

Float-over vessels are used to install large offshore structures, such as platforms, onto the seabed. The following steps summarize the operations of a float-over vessel:

1. Loading: The platform is loaded onto the vessel using cranes or other specialized equipment.
2. Transport: The vessel transports the platform to the installation site.
3. Positioning: The vessel uses dynamic positioning systems to maintain its position over the installation site.
4. Floating: The platform is floated over the prepared foundation on the seabed using ballast tanks or other specialized equipment.
5. Sinking: The platform is gradually sunk onto the foundation using controlled ballasting or other methods.
6. Securing: The platform is secured in place using mooring systems or other specialized equipment.
7. Completion: The installation process is completed and the vessel departs the site.

Float-over vessels are equipped with ballast control systems, dynamic positioning systems, and other specialized equipment to support the floating and sinking of the platform. The success of a float-over operation depends on precise control of the vessel's position and ballast, as well as the coordination of the various installation systems. Float-over vessels play an important role in the installation of offshore platforms and other structures in the offshore oil and gas industry.

Specialist systems which may be fitted to facilitate load transfer include:

- Leg mating units (LMUs) or shock absorbers fitted at the interface between the topside structure and the host structure or vessel to dampen vertical and horizontal motions and assist with even load distribution;
- Rapid load transfer systems such as hydraulic jacks – these may operate in conjunction with the ballast system to facilitate rapid transfer of the topside structure to/from the host structure and establishment of a safe clearance between the structure and the vessel.

Fendering systems may be used to allow contact to be tolerated without compromising structural integrity where the vessel operates in close proximity to structures or other vessels.

A motion compensated gangway may be provided to facilitate personnel transfer between the float- over vessel and the installation/decommissioning site.

Float-over operations are conducted in close proximity to offshore structures and may be assisted by tugs and other vessels. High accuracy position keeping is required.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel and its load and to the adjacent offshore installation or support vessels and environmental pollution.

IMC M103offers a whole section on the *A5-1 Industrial Mission* of ***Float-over Vessels.*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- *A5*-1 Industrial Mission
- *A5*-1.1 Description and Role
- *A5*-2 Design Guidance
- *A5*-2.1 Design Considerations
- *A5*-2.2 DP Capability
- *A5*-2.3 Control Systems

- *A5*-2.4 Reference Systems and Sensors
- *A5*-2.5 Power Systems
- *A5*-3.1 Operational Guidance
- *A5*-3.2 Operational Considerations
- *A5*-3.3 Communications
- *A58*-3.4 DP Alert Status
- *A5*-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	DGNSS (Inertial)
Relative GNSS	Relative GNSS
Acoustics (inertial) USBL	Acoustics (inertial) USBL
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for float over vessels and must be read in conjunction with IMCA M103 in its entirety.

A5-2.4 Reference Systems and Sensors

When position keeping relative to a fixed or floating host structure then at least two of the position references in use should be relative systems.

At least three independent position reference systems using a minimum of two measurement principles should be in use during float-over operations or when in close proximity to another vessel or structure.

At least three independent heading reference sensors for the DP system should be provided.

Reference systems should be selected so as to minimise possible degradation during load transfer, changes in draught and changes in position of the load.

Power for position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

When the vessel is manoeuvring clear of other vessels or structures then a minimum of two position reference systems should be in use with a third immediately available.

At least three independent wind sensors should be provided, positioned to allow for local disruption of wind flow caused by the load, information should be corrected to a common height at the DP control station.

IMCA M103offers the following operational considerations for float over vessels and must be read in conjunction with IMCA M103 in its entirety.

A5-3.1 Operational Considerations

The following should be considered when planning DP operations:

- *Float-over operations prior to mating and commencement of load transfer may be characterised by a short time to terminate. Once load transfer has commenced there may be no possibility to safely terminate the float-over before actual completion of the operation. This should be identified during operational planning and the duration of such activities minimised;*
- *Position instability may occur during periods of rapid load transfer;*
- *Due to the critical nature of vertical motion, consideration should be given to the detection of possible movements of fresh water (freshets) that could cause draught to change;*
- *The minimum float-over clearance will be determined based on vessel draught, environmental conditions and maximum motion amplitudes at the mating points;*
- *Where fenders are fitted to distribute contact load the effects of moderate horizontal forces experienced through such contact loads should be anticipated;*
- *Lifting operations are subject to wind and wave limits. Wind forces may be high due to the size and shape of the load, and may vary significantly depending on the position of vessel equipment such as cranes;*
- *The risk that radar or laser range-finding position reference instruments may have the line of sight with their target obstructed by the lift should be analysed and mitigated;*
- *A vessel emergency escape route should always be planned.*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

Accommodation vessels are equipped with various systems and amenities to support the comfort and well-being of personnel. These may include living quarters, recreation areas, medical facilities, and other amenities. Accommodation vessels play an important role in supporting offshore oil and gas operations, as well as in the construction and maintenance of offshore structures, such as wind turbines and pipelines.

The primary operational role of the vessel is to provide accommodation for a workforce engaged on an adjacent facility.

Accommodation vessels are required where sufficient accommodation is not available at the facility or where the facility lacks the necessary safety or evacuation equipment.

Accommodation vessels may be utilised where it is unsafe to provide accommodation on a facility due to the proximity of process hazards.

Accommodation vessels operate in close proximity to offshore facilities and other vessels.

Personnel transfer arrangements between the accommodation vessel and the facility may consist of gangways, boat landings and helicopter decks. For the purpose of this guidance it is assumed that personnel transfer is conducted by means of a gangway with the accommodation vessel being in close proximity to the facility it is supporting. The gangway may utilise active motion compensation.

Accommodation vessels may be fitted with a crane to transfer equipment and provisions from a support vessel. Theymayalsobeprovidedwithworkshopsorequipmenttofacilitatemaintenance and work tasks on the facility.

The accommodation vessel may provide temporary services to the adjacent facility such as power, water or firefighting services.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel and to the adjacent offshore installation or support vessels and environmental pollution.

IMC M103offers a whole section on the *A6-1 Industrial Mission* of ***Accommodation Vessels.*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A6-1 Industrial Mission
- A6-1.1 Description and Role
- A6-2 Design Guidance
- A6-2.1 Design Considerations
- A6-2.2 DP Capability
- A6-2.3 Control Systems
- A6-2.4 Reference Systems and Sensors
- A6-2.5 Power Systems
- A6-3.1 Operational Guidance
- A6-3.2 Operational Considerations
- A6-3.3 Communications
- A6-3.4 DP Alert Status
- A6-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	DGNSS (Inertial)
Relative GNSS	Relative GNSS
Acoustics (inertial) USBL	Acoustics (inertial) USBL
Tautwire (<400m)	Tautwire (<400m)
	Laser
	Radar
	Gangway

IMCA M103 offers the following guidance for position reference systems and sensors for accommodation vessels and must be read in conjunction with IMCA M103 in its entirety.

> *A6-2.4 Reference Systems and Sensors*
>
> *At least three independent position reference systems based on at least two different measurement principles should be used when transferring personnel or when in close proximity to a facility.*
>
> *If a seabed reference system needs to be relocated then two position references may be temporarily allowed providing the vessel is stationary with no DP system instability and the gangway is closed to traffic until three references are back in use.*
>
> *Reference systems should be selected so as to minimise possible interference from adjacent facilities.*
>
> *Power for position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.*
>
> *When the vessel is manoeuvring clear of other vessels or structures then a minimum of two position reference systems should be in use with a third immediately available.*
>
> *When position keeping relative to a facility that has small position excursions then at least two independent relative position reference systems should be available in conjunction with absolute systems.*
>
> *If the combined position excursions of the vessel and facility may exceed the operating limits of the gangway then the accommodation vessel should use relative reference systems only, allowing the vessel to follow facility movements, at least three relative reference systems should be provided.*
>
> *Relative position reference systems should be located as close to the gangway as possible so as to minimise the effects of errors in heading references and reference system offsets on the gangway position.*
>
> *If the gangway is used as a position reference for the DP system then the integrity of the position reference information should be subject to FMEA.*
>
> *At least three independent heading reference sensors should be provided.*

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational considerations for accommodation vessels and must be read in conjunction with IMCA M103 in its entirety.

A6-3.1 Operational Considerations

The following should be considered when planning DP operations:

- *Personnel transfer from an accommodation vessel is usually characterised by a short time to terminate. If the accommodation vessel is providing services such as fuel, water or power to the facility then the time for a controlled disconnection could be longer. If leaving personnel on the facility is not acceptable then the time to terminate should consider the time needed to recall all personnel via the gangway when determining operational configuration and limits;*
- *Accommodation arrangements are subject to coastal state administration approval. When positioned alongside a facility then the facility OIM may have responsibility for some aspects of the accommodation arrangements;*
- *Decisions relating to accommodation vessel movements should be made in co-operation between those on the vessel and the facility. Emergency arrangements should be agreed and documented in the ASOG to prevent actions during an emergency being delayed by prolonged communication. Some emergency situations on the facility may require that the accommodation vessel remains with the gangway connected during a DP yellow alert;*
- *Where permitted the accommodation vessel should move clear of the facility between personnel transfers to minimise exposure to risks associated with an inability to maintain position;*
- *The risk that radar or laser range-finding position reference instruments may have the line of sight with their target obstructed by personnel/equipment should be analysed and mitigated;*
- *Where position keeping is required relative to a floating facility an assessment of the facility's allowable position footprint and rate of movement should be completed to confirm that this does not exceed the capabilities of the accommodation vessel DP system and its gangway;*
- *A vessel emergency escape route should always be planned.*

WALK TO WORK

Accommodation vessels may have walt to work (W2W) gangway way solutions. Det Norske Veritas Ltd (DNV) created a joint industry project (JIP) who developed an industry guidance document to assist offshore facility operators in achieving safe and efficient personnel transfers to/from their facilities via a gangway.

They suggest that a W2W vessel may be required to have:

- *Specific station keeping and vessel manoeuvrability capabilities*
- *A certified helideck for defined helicopter type and operations*
- *Defined accommodation facilities for specified number of persons*
- *Man overboard or full standby vessel capability with 2 x FRCs with Personal Locator Beacon (PLB) tracking*
- *Specified deck cargo capability*
- *Hot-work fabrication workshop*
- *Craneage capability to defined specification*
- *Pipeline and jacket inspection ROV*

- *Inspection test and maintenance strategies that do not impact W2W operations o Motion monitoring & recording systems*
- *Radar Early Warning System (REWS) installed*
- *Work and rest limitations (e.g. working hours)*
- *Personnel minimum requirements such as training certificates*

We recommend that you read this document if you are on a vessel with a W2W gangway solution.

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

A drill ship is a type of mobile platform used for offshore drilling operations. It is equipped with a drilling rig and other necessary equipment for exploring and extracting oil or natural gas from beneath the ocean floor. The ship's design allows for mobility, enabling it to be positioned over various drilling sites. It typically has a large deck area for storing and handling drilling equipment, a drilling derrick, and living quarters for crew. It may also have storage tanks, processing equipment, and support vessels.

The primary operational role of the vessel is drilling wells into oil or gas reservoirs, or scientific drilling activities.

Drilling vessels may also be utilised for maintenance or completion activities on existing wells and are frequently provided with ROVs to facilitate subsea intervention, survey and inspection.

The DP operational requirement is to maintain the drilling vessel in a static position over the well site for the duration of the drilling operation. The drilling vessel may need to temporarily offset its position clear of subsea infrastructure to conduct tasks where dropped objects may pose a risk.

Drilling vessels, generally known as mobile offshore drilling units (MODU) may be self-elevating/ bottom standing, moored or dynamically positioned (DP); DP vessels have advantages in being able to transit independently, relocate rapidly between wells and operate in the greatest water depths.

Drilling vessels frequently operate in locations subjected to strong sea currents and large wave and wind forces.

DP drilling operations are generally conducted in open water away from fixed surface structures, but can also be conducted near fixed and floating surface structures. DP Drilling activities will be required to operate in close proximity to other vessels, for example offshore support vessels and/or ROV, construction, and seismic vessels.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel and to the drilling riser, wellhead, adjacent offshore installations and support vessels as well as environmental pollution.

IMC M103offers a whole section on the *A7-1 Industrial Mission* of ***Service Operations Vessels (SOV).*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A7-1 Industrial Mission
- A7-1.1 Description and Role
- A7-2 Design Guidance
- A7-2.1 Design Considerations
- A7-2.2 DP Capability
- A7-2.3 Control Systems
- A7-2.4 Reference Systems and Sensors
- A7-2.5 Power Systems
- A7-3.1 Operational Guidance
- A7-3.2 Operational Considerations
- A7-3.3 Communications
- A7-3.4 DP Alert Status
- A7-3.5 Responsibilities

MTS have developed and entire document for mobile offshore drilling units (MODUs) DP OPERATIONS GUIDANCE - PART 2 - APP 1 (Rev3 - Apr21) MODU. If you are serving on a MODU we recommend you access this document in full.

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	N/A
Acoustics (inertial) USBL & LBL	

DP OPERATIONS GUIDANCE - PART 2 - APP 1 (Rev3 - Apr21) MODU offers some in depth guidance on position reference systems on MODUs as follows.

3.11 REGIONAL RECOMMENDATIONS FOR DP DRILLING UNITS

3.11.1 Owners/ operators of DP drilling units should consider adopting the following standards for hydroacoustic and satellite systems for deepwater DP drilling operations. The adoption of these standards should enable the DP drilling unit to operate anywhere in the world.

3.11.2 Hydroacoustic Systems

• A minimum of two independent acoustic systems each one with internal redundancy as to transponders/ beacons and transducers/ hydrophones capable of operating in maximum specified water depths with such a configuration that allows a minimum of 0.5% of water depth in 95% of measurements. Each acoustic system should have redundancy in the input of sensors (gyros and VRUs) and each transducer/ hydrophone should have redundancy in electrical supply. Whilst making this recommendation it is recognised that there are many DP drilling units already in operation that are not equipped with dual independent acoustic systems. In such cases owners are encouraged to consider the benefits of upgrading to dual independent systems.

• Acoustic systems operating in a master/ slave relationship or hot standby should be avoided. They should simultaneously supply the DP controllers as totally independent position reference systems. The designation of weight or deselection of a faulty position reference system should be performed automatically by the DP controllers without DPO intervention.

Note In deepwater applications where weighting adjustments by DPO may be required, detailed procedures are to be provided.

The DP drilling unit should have a number of transponders/ beacons sufficient to constitute submarine arrays capable of operating in the maximum water depth, including redundancy on the bottom for the configuration of each operational mode and the back ups on the surface. In addition, DP drilling units should be provided with reliable deployment and retrieval systems such as the use of ROVs for deployment and retrieval and may also include acoustic release systems.

Where not fitted owners are encouraged to consider the benefits of providing, as an additional function, the primary actuation of the acoustic system driving the back up of BOP (with redundancy) via hull transducers. The BOP specific portable acoustic unit should be used only in exceptional circumstances, such as failure of the primary system or abandonment of the platform.

Cautionary Note where acoustic BOP systems are required, there is potential for interference by the use of equipment provided by multiple acoustic vendors.

• Consideration should be given to using USBL as a top down means of calibrating LBL systems. This will optimise calibration times as well as improving accuracy.

3.11.3 Satellite Based Systems

Two independent satellite positioning systems should be in operation, each with minimum accuracy of three meters. The primary receivers should have GPS dual frequency (L1/L2) in addition to one GLONASS receiver. Each system *should have double redundancy in the differential signal reception system as follows; two different satellite systems, for example, Inmarsat and Spot Beam and two different radio systems with distinct frequencies and redundant transmitter stations with range covering the whole operational scenario of the Unit (i.e. DP drillship or DP semi), for example, IALA MF and UHF.*

Note Availability of the local radio system Infrastructure varies by region.

Each satellite positioning system should have redundancy in the input of sensors (gyros and VRUs).

Antennae (both primary GPS and differential) should be situated in different places on the Unit spaced apart in order to guarantee redundancy and minimize shadow sectors.

The satellite systems should provide the DP controllers with positioning reference information simultaneously and independently.

IMCA M103 offers the following guidance for position reference systems and sensors for drill ships and must be read in conjunction with IMCA M103 in its entirety.

A7-2.4 Reference Systems and Sensors

At least three independent position reference systems should be in use for critical activities and three independent heading reference sensors should be in use for heading sensitive operations.

Reference systems should use a minimum of two different measurement principles.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

In deep water and open water locations there may be a reliance on satellite based position references, satellite based systems should be sourced from different manufacturers to avoid software induced common cause failures. Independence should be provided by the separation of power supplies. Different methods for differential corrections should be employed. No single failure should result in the loss of more than one position reference system. Consideration should be given to using position reference systems in combination with inertial navigation systems to filter short term instability.

A riser monitoring system may be interfaced to the DP control system. In such cases it is essential that the integrity of such information is confirmed prior to its use in the DP system and verified during operation, as sudden failure may have an impact on position control performance and stability.

Intrinsically safe equipment may be required where risks exist from flammable vapours.

Wind sensors should be positioned to allow for local disruption of wind flow caused by the drilling derrick, information should be corrected to a common height at the DP control station.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational considerations for drilling vessels and must be read in conjunction with IMCA M103 in its entirety.

A7-3.1 Operational Considerations

The following should be considered when planning DP operations:

- *Drilling operations often have a short time to terminate, however this is sensitive to the nature of the specific operation being undertaken, for example if a non-shearable is passing through the wellhead then time to terminate will be longer. The time taken to restart operations may be long following an emergency disconnect;*

- *The power demands of drilling activities may cause high transient loads;*
- *Wind forces on the vessel may be high due to the size and shape of the vessel structure;*
- *Vessel heading may be determined by the requirement for wind flow over the vessel to mitigate potential effects of gas release;*
- *Changes in riser flex joint angles as well as to position relative to the seabed need to be considered when monitoring vessel position;*
- *A vessel emergency escape route should always be planned. This should take account of bathymetry and seabed structures.*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

An FPSO (Floating Production Storage and Offloading) vessel is a type of floating facility used in the offshore oil and gas industry. It is used to extract, process, store, and offload crude oil and natural gas from underwater wells to shore. FPSOs have processing equipment on board to separate oil, gas, and water and to store the processed crude oil in tanks. The processed oil is then offloaded onto tanker ships for transportation to shore. FPSOs provide a flexible and cost-effective alternative to traditional fixed platforms, and are often used in deep-water or remote locations where onshore facilities are not available.

The term FPSO is an acronym for floating production storage and offloading; these terms describe the industrial mission of the vessel.

Production is the onboard processing, separation and treatment of crude oil, gases and water from subsea wells connected to the FPSO by risers.

Storage is the storage provided on board for the processed crude oil or gasses. These products may be transferred to shuttle tankers for shipment to shore-based facilities, removing the need for export pipelines.

The two mission activities of the FPSO may be separated and carried out by floating production units (FPUs) with no storage and floating storage and offloading vessels (FSOs) which have no production facilities. Such vessels are considered to be within the scope of guidance offered for FPSOs for the purposes of these guidelines.

FPSOs may be moored or dynamically positioned. DP FPSOs are favoured for short term use associated with extended well testing (EWT) for proving the commercial viability of a well. DP FPSOs may also be used as early production systems (EPS) to bring production online quickly whilst installation of permanent facilities progresses. EPS generally produce from more than one well, increasing the risks associated with an inability to maintain position.

FPSOs are frequently provided with ROVs to facilitate subsea intervention, riser connection, survey and inspection.

FPSOs frequently operate in locations subjected to strong sea currents and large wave and wind forces.

Operations are generally conducted in open water away from fixed surface structures, however they will be required to operate in close proximity to other vessels, for example supply vessels and shuttle tankers.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel, the riser, and support vessels as well as environmental pollution.

Refer to IMCA M 159 – *Guidance on thruster-assisted station keeping by FPSOs and similar turret-moored vessels.*

IMC M103offers a whole section on the A8-1 Industrial Mission of FPSO Vessels. While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A8-1 Industrial Mission
- A8-1.1 Description and Role
- A8-2 Design Guidance
- A8-2.1 Design Considerations
- A8-2.2 DP Capability
- A8-2.3 Control Systems
- A8-2.4 Reference Systems and Sensors
- A8-2.5 Power Systems
- A8-3.1 Operational Guidance
- A8-3.2 Operational Considerations
- A8-3.3 Communications
- A8-3.4 DP Alert Status

- A8-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	N/A
Acoustics (inertial) USBL & LBL	

IMCA M103 offers the following guidance for position reference systems and sensors for FPSO vessels and must be read in conjunction with IMCA M103 in its entirety.

> *A8-2.4 Reference Systems and Sensors*
>
> *At least three independent position reference systems should be in use for critical activities and three independent heading reference sensors should be provided.*
>
> *Reference systems should use a minimum of two different measurement principles, it is recommended to use three different measurement principles.*
>
> *Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.*
>
> *In deep water and open water locations there may be a reliance on satellite based position references, satellite based systems should be sourced from different manufacturers to avoid software induced common cause failures. Independence should be provided by the separation of power supplies. Different methods for differential corrections should be employed. No single failure should result in the loss of more than one position reference system. Consideration should be given to using inertial navigation systems to filter short term instability.*
>
> *Position references should be selected which support both auto position and weathervane modes of DP control.*
>
> *Hawser tensions related to the external forces applied by a shuttle tanker during offloading may be interfaced to the DP system to enable the thrusters to compensate effectively. A riser monitoring system may also be interfaced to the DP control system. In such cases it is essential that the integrity of such information is confirmed prior to its use in the DP system, as sudden failure may have an impact on position control performance and stability.*
>
> *Intrinsically safe equipment may be required where risks exist from flammable vapours.*
>
> *Wind sensors should be positioned to allow for local disruption of wind flow caused by the vessel design, information should be corrected to a common height at the DP control station.*

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational considerations for FPSO vessels and must be read in conjunction with IMCA M103 in its entirety.

> *A8-3.1 Operational Considerations*

The following should be considered when planning DP operations:

Production and offloading operations often have a short time to terminate. The time taken to restart operations may be long following an emergency disconnection of the riser turret. Such emergency disconnection may also result in the loss of the well;

Weathervane mode of control may demand high athwartship thrust if a rapid change in heading occurs in response to external forces; operators should be aware of the circumstances where change of mode to auto position is preferable;

The power demands of drilling activities may cause high transient loads;
Wind forces on the vessel may be high due to the size and shape of the vessel structure;

Vessel heading may be determined by the requirement for wind flow over the vessel to mitigate potential effects of gas release;

Changes in riser flex joint angles as well as to position relative to the seabed need to be considered when monitoring vessel position;

A plan for emergency disconnection and escape from the wellhead position should be readily available. This should consider that in the initial stages of disconnect the riser will recoil and extend its full length beneath the vessel, this should be considered when developing the ASOG/ WSOG;

Offloading operations to conventional shuttle tankers (not utilising dynamic positioning) may result in high hawser loads which will affect FPSO position keeping;

Control of position and communications with the shuttle tanker during offloading operations requires careful planning; weathervaning of the FPSO may not be appropriate during such operations unless the shuttle tanker is capable of following the changes in position and heading (see Appendix 9 relating to shuttle tanker operations).

IMCA M103offers the following operational planning for FPSO vessels and must be read in conjunction with IMCA M103 in its entirety.

A8-3.2 Operational Planning

Where appropriate the following should be documented:

- *Risk assessment for the loss of vessel position at all stages of the operation and for all associated activities, including SIMOPs;*
- *Configuration of DP systems for the critical activity mode of operation (CAM) or for the task appropriate mode (TAM) with specification as to which modes are required for each phase of the operation;*
- *Activity specific operating guidelines (ASOG) to define actions in the event of loss of DP critical system as well as defining environmental and equipment performance limits and guidance on required actions in the event of these limits being exceeded. Well specific operational guidelines may be appropriate;*
- *An interface document between offshore loading facility and shuttle tanker (may take the form of a joint operations manual (JOM)).*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

The role of the vessel is offshore loading of crude oil and condensates from production facilities followed by transporting these products to onshore terminals, providing an alternative to a fixed pipeline.

Offshore production facilities may produce directly into a shuttle tanker, or may have storage facilities which are periodically discharged to a shuttle tanker.

Shuttle tankers may also be used for lightening of larger tankers.

Shuttle tanker offshore loading operations may take place in any water depth which can accommodate the vessel's draught.

For offshore loading the tanker should be capable of maintaining position relative to the loading facility and be suitably equipped to connect to the loading system safely. The tanker should be able to enter designated discharge ports without undue restrictions and be capable of self-discharging.

Offshore loading facilities include (but may not be limited to):

- surface single point systems (including articulated loading platform (ALP)) and single buoy mooring (SBM);
- sub-surface single point systems including offshore loading system (OLS), submerged turret loading (STL), tripod catenary mooring system (TCMS), single anchor production (SAP) and single anchor loading (SAL);
- surface production and storage systems (including floating storage unit (FSU) systems and floating production storage and offloading (FPSO) systems).

The favoured approach for the shuttle tanker is directly into the prevailing environmental forces. However tankers may approach single point systems from any direction.

Surface production and storage systems will have a restricted approach sector for the shuttle tanker due to the arrangement of their offloading equipment. They may be spread moored in a fixed orientation, or may be turret moored and free to rotate.

Shuttle tanker offshore loading operations may be carried out as follows:

- Conventional (non-DP) tankers operating in benign environments may utilise a taut mooring hawser from the offshore loading facility to the bow of the shuttle tanker. Tug assistance may be provided for connection of the mooring hawser and to provide heading control in combination with tension in the mooring hawser. **Refer to: Tandem Mooring and Offloading Guidelines for Conventional Tankers at F(P)SO Facilities 1st Edition – OCIMF (2009);**
- DP equipped tankers utilising DP to maintain a position relative to the offshore loading facility**. Refer to IMCA M 159 – Guidance on thruster-assisted station keeping by FPSOs and similar turret- moored vessels;**
- Tankers which use a combination of thrusters with tug and/or mooring assistance; such systems are not considered to be dynamically positioned within the context of this guidance.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel and to adjacent offshore installations as well as environmental pollution.

IMC M103offers a whole section on the *A9-1 Industrial Mission* of ***Shuttle Tankers.*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A9-1 Industrial Mission
- A9-1.1 Description and Role
- A9-2 Design Guidance
- A9-2.1 Design Considerations
- A9-2.2 DP Capability
- A9-2.3 Control Systems

- A9-2.4 Reference Systems and Sensors
- A9-2.5 Power Systems
- A9-3.1 Operational Guidance
- A9-3.2 Operational Considerations
- A9-3.3 Communications
- A9-3.4 DP Alert Status
- A9-3.5 Responsibilities

MTS have produced Appendix B DP Shuttle Tanker Redundancy Concept Philosophy Document (April 2021) to their DP Vessel Design Philosophy Guidelines. This document is worth looking at even if you are not sailing in shuttle tankers.

MTS refers to this document as a Redundancy Concept Philosophy Document (RCPD).

One of its objectives is to explain the redundancy concept to the vessel crew using the example of a DP 2 shuttle tanker. The vessel they have used for this example has five independent equipment groups. The recommended color coding is used as seen in the diagram below.

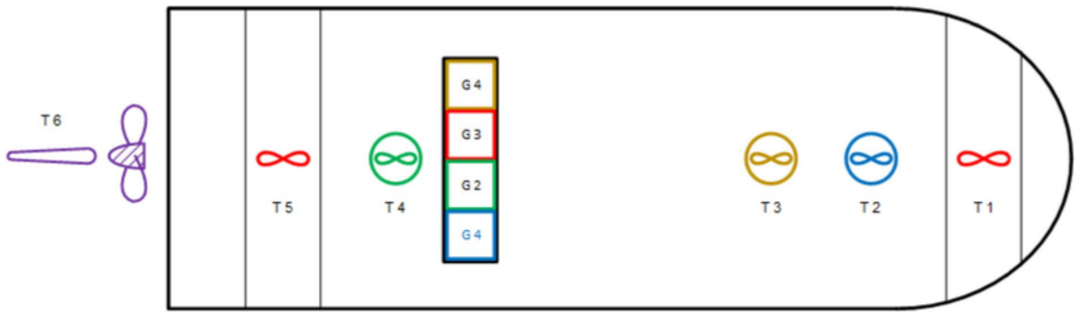


FIGURE 65 - MTS DP VESSEL DESIGN PHILOSOPHY GUIDELINES - APP B (REV2 - APR21)

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water (FPSO)	Close to a structure
DGNSS (Inertial)	N/A
Relative GNSS	
Microwave radar	
Laser	

IMCA M103 offers the following guidance for position reference systems and sensors for shuttle tankers and must be read in conjunction with IMCA M103 in its entirety.

A9-2.4 Reference Systems and Sensors

Position reference systems appropriate to the DP equipment class should be in use for offshore loading operations. The available systems should allow the DP operator to select a different measurement principle for each reference in use.

Position references should support both auto position and weathervane modes of DP control where necessary.

Three independent heading reference sensors should be in use for critical activities.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

Where the loading facility is free to move then at least two relative position reference systems should be provided in conjunction with an absolute position reference system. Where a combination of fixed and relative position reference systems are used and the relative target is free to move then specialist DP control software is required to compensate this movement in the position calculation.

Potential for interference to reference systems from obstructions, false targets or environmental conditions should be analysed and references chosen which minimise such interference.

Intrinsically safe equipment may be required where risks exist from flammable vapours.

For sub-surface loading facilities acoustic position reference systems may be employed to provide a relative reference. Absolutereferenceswithalimitedscope,suchastautwire,willnotgenerally be suitable.

Wind sensors should be positioned to allow for local disruption of wind flow caused by the vessel's shape and structure and should be corrected to a common height at the DP control station.

If a mooring hawser is to be used during DP operations then a hawser tension sensor should be interfaced to the DP system to enable the thrusters to compensate effectively; this should be subject to FMEA.

The vessel draught sensors should be interfaced to the DP system.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational planning for shuttle tankers vessels and must be read in conjunction with IMCA M103 in its entirety.

A9-3.2 Operational Considerations

The following should be considered when planning DP operations:

- *Offshore loading operations are usually characterised by a short time to terminate. ESD systems should allow a quick termination of loading and disconnection of hoses and hawser.*
- *Fixed orientation surface production and storage facilities (spread moored) will limit the shuttle tanker's ability to use a weathervane mode. A non-optimal heading may require high athwartship thrust to maintain position, and risks high hawser tensions;*
- *A weathervaning mode of positioning may be used by shuttle tankers loading from rotating surface production and storage facilities (turret moored) however specialist DP control modes will be required due to the movement of the reference loading point. Differences in draught and wind profile between the shuttle tanker and the facility may necessitate each adopting different weathervane headings as they may react differently to changes in wind and current;*
- *Shuttle tankers adopting a weathervane mode are generally in a drift-off position in the event of positioning system failure;*
- *Where the heading of a surface production and storage facility can be controlled, such changes should be carefully managed, with procedures and communications for heading changes being agreed and clearly documented;*

- *Using tug assistance in conjunction with DP control is problematic as the forces applied by the tug may be unknown to the DP system and tug towing forces may be subject to a variety of single point failures;*
- *Weather working limits for connecting and loading phases are usually defined by the field operator. Hose connection is generally the most weather sensitive operation;*
- *In areas subjected to rapid current changes then the actions of the DPO in responding to such changes should be defined and recorded in appropriate procedures;*
- *If the shuttle tanker experiences a total black out whilst moored to the loading facility an emergency disconnect of the mooring hawser may not always be desirable. Decision support should accompany the ASOG;*
- *Shuttle tanker DPOs require specific training to ensure familiarity with the vessel operations, DP control modes, manual vessel control, ESD procedures and means of disconnection and vessel escape in the event of DP system failure. Training in an environment similar to the proposed working locations with simulated conditions is recommended. The training should also include drift off patterns for the DP vessel at the installation location.*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

A trenching vessel is a type of specialized ship used in the offshore oil and gas, renewable energy, and telecommunications industries to install and maintain subsea pipelines and cables. It is equipped with specialized machinery, such as plows or jet trenchers, that can dig a trench in the seabed to lay the pipelines or cables in. Trenching vessels are also equipped with machinery to backfill the trench and protect the pipeline or cable. The purpose of trenching is to provide stability and protection for the pipelines and cables, and to prevent damage from fishing gear or anchor drops. Trenching vessels are essential for the development and maintenance of subsea infrastructure in offshore operations.

Trenching techniques include:

- ploughing – a trench is formed by towing a plough;
- jetting – the seabed is liquefied using high pressure water jets allowing an existing pipeline or cable to sink into the seabed, or the liquefied material is pumped or ducted away to form an open trench;
- mechanical cutting – rotating cutting tools cut or erode seabed materials to form a trench;
- dredging – dredging vessels such as cutter suction dredgers, bucket dredgers or trailing suction
- hopper dredgers remove seabed materials in advance of pipeline or cable installation.

Trenchers may be either self-propelled or towed by the trenching vessel. The towing force required depends upon the type of trencher used and the nature of the seabed.

The trenching vessel should be capable of track-keeping whilst maintaining the correct tension in the trencher towline (where applicable).

In addition to trenching operations in open water there may be occasions where trenching is required in close proximity to fixed or floating structures or in close proximity to the shore where cables and pipelines make landfall.

Multi-purpose vessels are frequently fitted with a crane and/or A-frame to facilitate launch and recovery of trenchers. Towing winches may be required where high tensions in trencher towline are required. ROVs may be provided to support trenching activities and for seabed survey and inspection.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel, pipelines, cables adjacent offshore installations as well as environmental pollution.

IMC M103offers a whole section on the *A10-1 Industrial Mission* of ***Trenching Vessels.*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A10-1 Industrial Mission
- A10-1.1 Description and Role
- A10-2 Design Guidance
- A10-2.1 Design Considerations
- A10-2.2 DP Capability
- A10-2.3 Control Systems
- A10-2.4 Reference Systems and Sensors
- A10-2.5 Power Systems
- A10-3.1 Operational Guidance
- A10-3.2 Operational Considerations
- A10-3.3 Communications
- A10-3.4 DP Alert Status
- A10-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS	DGNSS
Acoustics USBL	Acoustics USBL
Tautwire (<400m)	Tautwire (<400m)
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for trenching vessels and must be read in conjunction with IMCA M103 in its entirety.

> *A10-2.4 Reference Systems and Sensors*
>
> *At least three independent position reference systems should be in use for critical trenching operations and three independent heading reference sensors in use for heading sensitive operations.*
>
> *Acoustic systems may be required to monitor subsea vehicles/equipment as well as to act as a position reference system.*
>
> *For DP equipment class 2 or 3 vessels, power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.*
>
> *In shallow water, or when working in close proximity to offshore installations, at least two different measurement principles should be employed for the reference systems. Consideration should be given to potential interference with seabed reference systems such as taut wire or acoustics due to strong currents, noise or suspended particles in the water column caused by the trenching operation.*
>
> *In deep water and open water locations there may be a reliance on satellite based position references; satellite based systems should be sourced from different manufacturers to avoid software induced common cause failures. Independence should be provided by the separation of power supplies. Different methods for differential corrections should be employed. No single failure should result in the loss of more than one position reference system. Consideration should be given to using position reference systems in combination with inertial navigation systems to filter short term instability.*
>
> *Use of acoustic beacons fitted to a self-propelled trencher machine as a relative position reference system should be avoided unless absolute reference systems are also utilised in the position calculation.*
>
> *A towline tension sensor may be interfaced to the DP control system, in such cases it is essential that the tension input is accurate, redundant and reliable. This also applies to any winch used to assist particular operations. Where redundancy or fail safe cannot be demonstrated then manual input of towline tension should be considered and rapid changes in tension avoided.*

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational planning for trenching vessels and must be read in conjunction with IMCA M103 in its entirety.

A10-3.1 Operational Considerations

The following should be considered when planning DP operations:

- *Depending on the technique adopted, trenching may be characterised by a relatively long time to terminate. Wheretrenchingofanexistingcableorpipelineistakingplacethenintervention may be required using a crane or ROV to recover the trenching machine safely;*
- *Environmental limits may be lower for launch and recovery of trenching devices than they are for actual trenching operations;*
- *Significant propulsion power may be required to maintain towline tension; this may reduce the position keeping capability in response to environmental forces;*
- *Availability and diversity of position references may be limited in open water and deep water when the vessel is moving during the trenching operation;*
- *The trenching activity may restrict choice of heading;*
- *Landfall and shallow water activities may be subject to more strict environmental and vessel motion limits than those for deep water and open water activities;*
- *Safe under-keel clearance requires careful consideration in shallow water. In addition to conventional grounding risks, thruster efficiency may be reduced and vessel pitching and rolling may reduce under-keel clearance significantly;*
- *Seabed position reference systems may be subject to interference or may have very limited scope in shallow water;*
- *Rapid changes in tow tension may cause instability in position if not accurately modelled in the DP system;*
- *Accurate positioning of non-self-propelled trenching equipment may be difficult if any elasticity exists in the towline system; the trenching equipment may move ahead uncontrollably when a softer seabed is encountered or may be diverted from the intended track under the influence of localised changes in seabed density. These considerations are important when operating close to other seabed infrastructure;*
- *The master and DPOs should be aware of the required tensions used for trenching operations and the appropriate emergency responses;*
- *The trenching supervisor should have instruction in the basic operation of the dynamic positioning system and the capabilities of the vessel in order to understand the potential vessel responses to requests for changes in position.*

CABLE LAY/REPAIR VESSELS (NOT SPECIFIED BY NAUTICAL INSTITUE)

See also Pipe Lay Vessels

The cable lay vessel's operational role is the installation, burial and maintenance of submarine communication and power cables. Cable repair includes the recovery, cutting and splicing and redeployment of submarine cables.

Cable lay operations may comprise any of the following phases:

- Cable shore landing – requiring the vessel to approach close to the shore landing position and then floating or dragging of the cable ashore. The shore landing may be either trenched or a horizontally drilled pipe which crosses under the shoreline;
- Subsea lay – using tensioners to lower cable to the seabed at a controlled speed; lowering speed and cable catenary will be dictated by seabed contours, vessel speed and the requirements of the trencher (if in use);
- Cable trenching – required in waters where the cable is vulnerable; may utilise a towed plough or water jetting machine;
- Offshore cable jointing or pull-in to offshore structure – if the cable must be jointed offshore then specialist expertise and equipment is employed. If the cable is terminated at an offshore structure then pull-in procedures are used to pull the cable end into a purpose-built guide at the base of the structure;
- Cable inspection and testing – final survey of the cable to ensure trenching has been effective, or to bury exposed and vulnerable sections.
- Cable repair operations generally comprise the following:
- Grappling for and cutting the cable – a towed cutting grapnel locates, cuts and lifts the first end of the cable;
- Buoying off the first end – carried out in preparation for subsequent recovery when making the final splice;
- Grappling for the second end – a towed grapnel is used to lift the cable second end in the region where repair is required;
- Jointing – once the damaged cable section is removed, a section of spare cable of a length at least twice the water depth is joined to the second end;
- Final splice – the buoyed first end is recovered and the final splice made to the inserted spare cable. The splice is then laid to the seabed in a long loop to maintain a minimum bend radius;
- Burial – required if the final splice loop is vulnerable to damage from marine activity or strong currents.

Trenching operations may require a significant bollard pull.

Operations may take place in any water depth such as shallow water close to shore for shore landing and in deep ocean waters for intercontinental connections.

Cable lay may be required in close proximity to inshore or offshore structures.

Vessels may be provided with trenchers for cable burial and ROVs to facilitate survey, inspection and intervention. Cranes or A-frames may be fitted for trencher and buoy deployment and recovery.

The consequences of loss of vessel position may include injury to personnel, damage to the vessel, cables, adjacent offshore installations as well as environmental pollution. Open water and deep water operations are generally tolerant of a large vessel position footprint.

IMC M103offers a whole section on the *A11-1 Industrial Mission* of ***Cable Lay/Repair Vessels.*** While we cannot reproduce the section here in its entirety we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A11-1 Industrial Mission
- A11-1.1 Description and Role
- A11-2 Design Guidance
- A11-2.1 Design Considerations
- A11-2.2 DP Capability
- A11-2.3 Control Systems
- A11-2.4 Reference Systems and Sensors

- A11-2.5 Power Systems
- A11-3.1 Operational Guidance
- A11-3.2 Operational Considerations
- A11-3.3 Communications
- A11-3.4 DP Alert Status
- A11-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	DGNSS (Inertial)
Acoustics (inertial) USBL & LBL	Acoustics (inertial) USBL & LBL
Tautwire (<400m)	Tautwire (<400m)
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for cable lay vessels and must be read in conjunction with IMCA M103 in its entirety.

A11-2.4 Reference Systems and Sensors

At least three independent position reference systems should be in use for critical cable laying operations and three independent heading reference sensors in use for heading sensitive operations.

Acoustic systems may be required to monitor subsea vehicles/equipment as well as to act as a position reference system.

For DP equipment class 2 or 3 vessels, power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

In shallow water, or when working in close proximity to offshore installations, at least two different measurement principle should be employed for the reference systems. Consideration should be given to potential interference with seabed reference systems such as taut wire or acoustics due to strong currents, noise or suspended particles in the water column.

In deep water and open water locations where an inability to maintain position is not deemed critical there may be a reliance on satellite based position references.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational planning for cable lay vessels and must be read in conjunction with IMCA M103 in its entirety.

A11-3.1 Operational Considerations

The following should be considered when planning DP operations:

- *Cable lay operations may be characterised by a short time to terminate where the cable can be cut and abandoned for future recovery. Time to restart after such abandonment may be significant;*
- *Time to terminate may be long if the cable is not cut, or cannot be cut part way through the lay;*
- *Cable lay and repair operations may tolerate a large vessel position footprint in open water and deep water;*
- *Significant propulsion power may be required to maintain a towline tension if trenching in conjunction with cable laying; this may reduce the position keeping capability in response to environmental forces;*
- *Availability and diversity of position references may be limited in open water and deep water, and when the vessel is moving during cable lay;*
- *Choice of heading may be restricted during cable lay;*
- *Shore landing and shallow water activities may be subject to more strict environmental and vessel motion limits than those for deep water and open water activities;*
- *Safe under-keel clearance requires careful consideration in shallow water. In addition to conventional grounding risks, thruster efficiency may be reduced and vessel pitching and rolling may reduce under-keel clearance significantly;*
- *Seabed position reference systems may be subject to interference or may have very limited scope in shallow water;*
- *Synchronisation between vessel speed and cable lay speed is required to maintain correct cable lay tension and catenary;*
- *The master and DPO should be aware of the procedures for cable lay and repair to the extent necessary to understand the requirements for vessel speed, cable tensions and trencher towline tensions;*
- *The cable lay supervisor should have instruction in the basic operation of the dynamic positioning system and the capabilities of the vessel in order that they understand the potential vessel responses to requests for changes in position*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

jack up vessel is a type of offshore drilling rig that is used in the exploration and production of oil and gas. It consists of a mobile barge with legs that can be extended to the seabed to support the rig. The jack up vessel is capable of drilling in water depths ranging from 50 to 400 feet.

The legs of the jack up vessel are jacked up or lowered to the seabed to provide stability for the drilling operation, and once in position, the vessel is not moved until the drilling is completed. Jack up vessels are equipped with drilling and production equipment, living quarters for workers, and other necessary facilities. They provide a cost-effective and flexible alternative to fixed platforms and are often used in shallow-water drilling operations.

Touch-down is the moment that the first leg makes contact with the seabed and represents the commencement of transfer of position control from the DP system to the legs. Lift-off is the moment the last leg is retracted from the seabed and represents the completion of transfer of position control from legs to the DP system.

A gangway may be fitted to facilitate personnel transfers.

Jack-up vessels are also called self-elevating vessels, their mission activities include:

- windfarm installation;
- drilling of oil and gas wells;
- well maintenance;
- offshore construction and decommissioning;
- accommodation.

IMC M103offers a whole section on the *A12-1 Industrial Mission* of ***Jack-up Vessels.*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A12-1 Industrial Mission
- A12-1.1 Description and Role
- A12-2 Design Guidance
- A12-2.1 Design Considerations
- A12-2.2 DP Capability
- A12-2.3 Control Systems
- A12-2.4 Reference Systems and Sensors
- A12-2.5 Power Systems
- A12-3.1 Operational Guidance
- A12-3.2 Operational Considerations
- A12-3.3 Communications
- A12-3.4 DP Alert Status
- A12-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS	DGNSS
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for jack-up vessels and must be read in conjunction with IMCA M103 in its entirety.

A12-2.4 Reference Systems and Sensors

At least three independent position reference systems employing at least two different measurement principles should be used during touch-down and lift-off, and when in close proximity to surface or seabed structures.

Reference systems should minimise the risk of degradation during touch-down, changes in draught and changes in deployment depth of legs. These risks include attenuation of acoustic systems' reception, variation in relative line-of-sight measurements as hull elevation varies and protruding legs interfering with satellite systems.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

When manoeuvring clear of other vessels or structures following lift-off then a minimum of two position reference systems should be in use with a third immediately available.

At least three independent heading reference sensors for the DP system should be provided due to the critical nature of heading control.

At least three independent wind sensors should be provided, these should be installed in different locations to allow for local disruption of wind flow caused by leg position. Where wind sensors are mounted at different heights then information at the DP control station should be corrected to a common height.

Additional sensors may be required for specialist jack-up DP modes to address the problems outlined in section A12-2.3:

- *Sea current vector sensors – to facilitate thruster compensation for the prevailing current following lift-off;*
- *Leg position sensors – to facilitate automatic modification of wind and hydrodynamic profile in the DP control system;*
- *Leg touch-down sensors – to facilitate an automatic freeze of DP model integral for environment compensation and avoid over-stressing the legs.*

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103offers the following operational planning for cable lay vessels and must be read in conjunction with IMCA M103 in its entirety.

The following should be considered when planning DP operations:

- *Jacking operations may be subject to strict wind, wave and sea current limits. Wind forces may be high due to the size and shape of the vessel structure, and may vary significantly depending on the position of legs and cranes;*
- *Position instability may occur during transfer from hull buoyancy to leg support and vice versa;*
- *The legs may be over stressed following touch-down if thruster forces are too high;*
- *Transit speed will be limited if legs protrude below the vessel hull in transit; drag due to water flow may overstress the leg structure;*
- *Some types of position reference system may be degraded during specific phases of the jacking operation, this should be risk assessed prior to starting elevation;*
- *An emergency vessel escape route should always be planned;*
- *The joystick may be used following lift-off if position keeping is unstable;*
- *Significant changes in vessel stability occur due to the change in position of the centre of gravity of the legs during the jacking process;*
- *Seabed stability and topography should be assessed prior to any project; general feasibility studies, including checks for punch-through resistance and fatigue may be required;*
- *The master and each DPO should be aware of the hazards associated with touch-down and lift-off, and the appropriate emergency responses following failures;*
- *The leg jacking control operator should have instruction in the basic operation of the DP system and the vessel's capabilities so as to understand the potential vessel responses during periods of touch-down and lift-off.*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

An offshore support vessel (OSV) is a type of ship that provides support services to offshore oil and gas platforms, wind farms, and other offshore installations. It is typically equipped with cranes, winches, and other specialized equipment that enables it to perform a range of tasks such as transporting personnel and supplies, installing and maintaining subsea equipment, and conducting survey and inspection work.

OSVs play a crucial role in maintaining the safety and efficiency of offshore operations. They also provide a platform for emergency response and evacuation, and are equipped with firefighting, life-saving, and medical facilities. The design of OSVs varies depending on the specific needs of the offshore operations they support, and they can range from small, highly manoeuvrable vessels to larger, more specialized ships.

The consequences of loss of vessel position may not be significant if the vessel is working in a blow- off position without hoses connected to the receiving installation/vessel, in such a position however there would be potential pollution if hoses were connected. If the inability to maintain position results in contact with the receiving installation/vessel then the consequences can be serious in terms of safety of people, the vessel, installation and environmental pollution.

IMC M103offers a whole section on the *A13-1 Industrial Mission* of ***Offshore Supply Vessels (OSV).*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A13-1 Industrial Mission
- A13-1.1 Description and Role
- A13-2 Design Guidance
- A13-2.1 Design Considerations
- A13-2.2 DP Capability
- A13-2.3 Control Systems
- A13-2.4 Reference Systems and Sensors
- A13-2.5 Power Systems
- A13-3.1 Operational Guidance
- A13-3.2 Operational Considerations
- A13-3.3 Communications
- A13-3.4 DP Alert Status
- A13-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	DGNSS (Inertial)
Relative GNSS	Relative GNSS
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for offshore support vessels and must be read in conjunction with IMCA M103 in its entirety.

A13-2.4 Reference Systems and Sensors

At least three independent position reference systems should be provided, when in close proximity to structures and installations they should employ at least two different measurement principles.

At least two relative position reference systems should be provided when working alongside floating structures/vessels.

OSVs are commonly provided with two satellite based position references. Where interference from adjacent structures may prevent such systems working then alternative reference systems should be provided to prevent position errors caused by such interference.

Contractual requirements and risk assessment will influence the number and type of position references required for specific locations. ***Additional guidelines may be found in 182 MSF.***

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

The DP control system should incorporate a feed forward signal to compensate for potential reaction forces from firefighting monitors (where fitted) if it is intended to operate the vessel in DP whilst using the monitors, otherwise station keeping may become unstable.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103 offers the following operational considerations for cable lay vessels and must be read in conjunction with IMCA M103 in its entirety.

A13-3.1 Reference Documents

Detailed operational guidance for offshore supply vessels is available in the following documents:

- *182 MSF – International guidelines for the safe operation of dynamically positioned offshore supply*
- *vessels;*
- *Marine Safety Forum, et al – Guidelines for Offshore Marine Operations (GOMO).*

A13-3.2 Operational Considerations

The following should be considered when planning DP operations:

- *Supply operations are frequently characterised by a very short time to terminate however this will increase if hoses are connected;*
- *Vessel operational limits should be determined by risk assessment;*
- *The capability, environmental limits and reliability required from the DP system will be*
- *influenced by the risk assessment for an inability to maintain position;*
- *Operational limits in excess of the vessel's capability following worst case failure may be allowable if the time to terminate is very short, there is a clear escape route in a blow-off position and where the risk assessment demonstrates a tolerable risk.*

ANCHOR HANDLING

The anchor handling vessel's (AHV) operational role is the deployment and recovery of anchors for floating offshore facilities. Considerable caution needs to be exercised when utilising DP for anchor handling to compensate for outboard tension caused by the anchor line. AHVs may also be called anchor handling tugs (AHTs).

AHVs may also undertake other activities:

- towing floating facilities to their intended location prior to running anchors and towing cargo barges to offshore construction sites; towing activities do not generally utilise DP;
- hold-back activities such as acting as a brake during shuttle tanker approaches to offloading facilities, shuttle tanker heading control using taut towlines and weathervaning FPSOs when operations require a constant heading. Such activities may utilise DP;
- offshore supply operations in the same manner as OSVs. Such vessels are categorised as anchor handling tug supply vessels (AHTSs). Supply operations frequently use DP for position keeping.

AHTs or AHTSs may be provided with A-frames, oil recovery systems, firefighting monitors and ROV systems to undertake additional industrial missions however the primary role remains anchor handling.

AHVs are characterised by an open deck area aft, with separate winches for anchor handling work wires and towing wires located abaft the accommodation.

AHVs often operate in areas susceptible to strong currents and large wave and wind forces, environmental limits may relate to DP position keeping capability, or to vessel motions caused by the sea state.

Anchor handling activities take place in both shallow and deep water – maximum depth of water for anchor handling activities is limited by the capability of AHVs and the anchoring equipment.

The consequences of loss of vessel position are dependent on the nature of the operation being conducted. The most critical activities occur when operating in close proximity to another vessel or installation. An inability to maintain position during heading control operations may be a significant risk if maintaining heading is critical for parallel activities; such risks may be mitigated by the use of more than one AHT.

IMCA M103 offers a whole section on the *A14-1 Industrial Mission* of ***Anchor Handling Vessels (AHV).*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A14-1 Industrial Mission
- A14-1.1 Description and Role
- A14-2 Design Guidance
- A14-2.1 Design Considerations
- A14-2.2 DP Capability
- A14-2.3 Control Systems
- A14-2.4 Reference Systems and Sensors
- A14-2.5 Power Systems
- A14-3.1 Operational Guidance
- A14-3.2 Operational Considerations
- A14-3.3 Communications
- A14-3.4 DP Alert Status
- A14-3.5 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS	DGNSS
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for anchor handlers and must be read in conjunction with IMCA M103 in its entirety.

> *A14-2.4 Reference Systems and Sensors*
>
> *At least three independent position reference systems should be provided, when in close proximity to structures and installations they should employ at least two different measurement principles.*
>
> *At least two relative position reference systems should be provided when working alongside floating structures/vessels.*
>
> *Tension sensors for anchor handling and towing winches should be interfaced to the DP system where such tensions are likely to affect position keeping.*
>
> *External force inputs to DP are to be accurate and reliable; sudden failure may have an impact on position keeping performance and stability.*
>
> *Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.*
>
> *The DP control system should incorporate a feed forward signal to compensate for potential reaction forces from firefighting monitors (where fitted) if it is intended to operate the vessel in DP whilst using the monitors, otherwise station keeping may become unstable.*

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103 offers the following operational considerations for anchor handlers and must be read in conjunction with IMCA M103 in its entirety.

> *A14-3 Operational Guidance A14-3.1 Reference Documents*
>
> *Operational guidance for anchor handling vessels is also available in the following document: Marine Safety Forum, et al – Guidelines for Offshore Marine Operations (GOMO).*
>
> *A14-3.2 Operational Considerations*
>
> *The following should be considered when planning DP operations:*
>
> - *Anchor handling operations are most frequently characterised by a short time to terminate as winch loads can be released quickly, the consequences of rapid termination will vary according to the stage of the operation in progress;*
> - *Vessel operational limits should be determined by risk assessment;*

- *The capability, environmental limits and reliability required from the DP system will be influenced by the risk assessment for an inability to maintain position;*
- *Operational limits in excess of the vessel's capability following worst case failure may be allowable if the time to terminate is very short, there is a clear escape route in a blow-off position and where the risk assessment demonstrates a tolerable risk;*
- *In most mission activities tow tension may be reduced to assist position keeping however the criticality of towing tension should be understood and if necessary operational limits adopted to ensure tow tension can be maintained after worst case failure.*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

A well stimulation vessel is a type of ship used in the offshore oil and gas industry to perform well stimulation services on offshore wells. Well stimulation refers to a range of processes used to improve the flow of oil and gas from a well, such as hydraulic fracturing or acidization.

Well stimulation vessels are equipped with specialized equipment and machinery, such as pumps, tanks, and chemical mixing systems, which are used to perform well stimulation treatments. They also have living quarters for workers, as well as firefighting and emergency response equipment. The design and specifications of well stimulation vessels vary depending on the specific needs of the well stimulation operations they support.

Well stimulation vessels provide a cost-effective and flexible alternative to onshore well stimulation facilities, and are often used in deep-water or remote locations where onshore facilities are not available. They play a critical role in maximizing the production of oil and gas from offshore wells and are essential for the development and maintenance of offshore oil and gas operations.

IMCA M103 offers a whole section on the *A15-1 Industrial Mission* of ***Well Stimulation Vessels.*** While cannot we reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- *A15-1 Industrial Mission*
- *A15-1.1 Description and Role*
- *A15-2 Design Guidance*
- *A15-2.1 Design Considerations*
- *A15-2.2 DP Capability*
- *A15-2.3 Control Systems*
- *A15-2.4 Reference Systems and Sensors*
- *A15-2.5 Power Systems*
- *A15-3.1 Operational Guidance*
- *A15-3.2 Operational Considerations*
- *A15-3.3 Communications*
- *A15-3.4 DP Alert Status*
- *A15-3.5 Responsibilities*

Of particular interest are A15-1.1 Description and Role

The vessel's operational role is to facilitate oil or gas well intervention to restore or enhance productivity. Stimulation may comprise hydraulic fracturing treatment or matrix treatment.

Well stimulation vessels have facilities for chemicals storage, blending and pumping. High pressure hoses are generally fitted on reels on the stern of the vessel for connection to the well bore.
Well stimulation operations are usually conducted by connecting to the well through a Christmas tree on surface installation, requiring the vessel to be positioned in close proximity to the installation for prolonged periods.

Environmental limits may be determined by the DP position keeping capability, or by vessel motions caused by the sea state.

The consequences of loss of vessel position depend upon the location of the vessel in relation to surface structures and whether the vessel is connected to the well. Pollution from well stimulation acids may result if hoses are damaged. Injury to personnel and severe damage to the vessel or surface structure may occur in the event of an inability to maintain position leading to collision.

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS (Inertial)	DGNSS (Inertial)
Acoustics (inertial) USBL	Acoustics (inertial) USBL
Tautwire (<400m)	Tautwire (<400m)
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for well stimulation vessels and must be read in conjunction with IMCA M103 in its entirety.

A15-2.4 Reference Systems and Sensors

At least three independent position reference systems should be provided; when in close proximity to structures and installations they should employ at least two different measurement principles.

At least two relative position reference systems should be provided when working alongside floating structures/vessels. Where relative reference systems are susceptible to interference (for example from cranes, structures and environmental conditions) then the potential for loss of position references should be risk assessed and suitable alternatives provided.

Well stimulation vessels are commonly provided with two satellite based position references. Where interference from adjacent structures may prevent such systems working then alternative reference systems should be provided to prevent position errors caused by such interference.

Contractual requirements and risk assessment will influence the number and type of position references required for specific locations.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103 offers the following operational considerations for well stimulation and must be read in conjunction with IMCA M103 in its entirety.

A15-3.1 Operational Considerations

The following should be considered when planning DP operations:

- *Well stimulation operations usually have a short time to terminate. Hoses will generally be provided with emergency quick releases however time to restart after a quick release may be significant. A controlled termination of pumping and disconnection of hoses will generally require assistance from the adjacent installation;*
- *The vessel should be capable of a controlled termination of operations following a single worst case failure. A risk assessment should determine the environmental operating limits for the vessel and the acceptable position excursion limit;*

- *Availability and diversity of position reference systems should be suitable for the specific operational location.*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

A rock placement vessel is used to place rocks, gravel, or other material on the seabed for erosion protection, scour protection, or to create artificial reefs. The following outlines the general operations of a rock placement vessel:

1. Preparation: Before a rock placement operation, the vessel is loaded with the required quantity of rocks or material to be placed. The vessel is also equipped with the necessary machinery, such as cranes and hoppers, to carry out the placement.
2. Navigation: The vessel navigates to the location where the rock placement is to take place. This location is usually determined based on the specific requirements of the project, such as the need for erosion protection or the creation of an artificial reef.
3. Placement: Once the vessel is in position, the cranes and hoppers are used to place the rocks or material on the seabed in the desired location. The rocks or material are placed in a specific pattern to ensure proper coverage and maximum protection.
4. Monitoring: The vessel continuously monitors the placement of the rocks or material to ensure proper placement and coverage. The vessel may need to make adjustments to the placement pattern to ensure the desired results.
5. Completion: Once the placement is complete, the vessel returns to port for unloading and maintenance. The placement of the rocks or material is monitored over time to assess its effectiveness and make any necessary adjustments.

The operations of a rock placement vessel are performed to ensure the protection of offshore structures and marine habitats, as well as to promote the growth of marine life. The vessel plays a critical role in maintaining the safety and efficiency of offshore operations and is essential for the development and maintenance of offshore oil and gas, renewable energy, and telecommunications industries.

IMCA M103 offers a whole section on the *A16-1 Industrial Mission* of ***Rock Placement Vessels*** . While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- *A16-1 Industrial Mission*
- *A16-1.1 Description and Role*
- *A16-2 Design Guidance*
- *A16-2.1 Design Considerations*
- *A16-2.2 DP Capability*
- *A16-2.3 Control Systems*
- *A16-2.4 Reference Systems and Sensors*
- *A16-2.5 Power Systems*
- *A16-3.1 Operational Guidance*
- *A16-3.2 Operational Planning*
- *A16-3.3 Communications*
- *A16-3.4 DP Alert Status*
- *A6-3.5 Responsibilities*

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS	DGNSS
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for rock placement vessels and must be read in conjunction with IMCA M103 in its entirety.

A16-2.4 Reference Systems and Sensors
At least three independent position reference systems should be provided for critical activities and when in close proximity to structures and installations. When in close proximity to structures or installations they should employ at least two different measurement principles, one of which should be a relative reference between the vessel and adjacent installation/structure.

The availability and diversity of position reference systems in open water when engaged in a follow- target mode may be limited.

Where relative reference systems are susceptible to interference (for example from cranes, structures and environmental conditions) then the potential for loss of position references should be risk assessed and suitable alternatives provided.

The use of the fall pipe ROV acoustic beacon as a 'fixed' position reference to facilitate a constant offset between vessel and ROV should be avoided as this would necessitate the use of a single reference in the DP system and risk unexpected high vessel power demand in the event of rapid ROV changes in speed or direction.

In deep water or when engaged in relative location DP mode in open water a reliance on satellite based position references may be acceptable if the risk associated with an inability to maintain position is low. Such allowable configurations should be clearly documented in the CAM/TAM.

Acoustic position reference systems are frequently used to track mobile ROV beacons, the number of beacons interrogated and frequencies used should be selected so as to minimise the potential for interference with DP position references. The potential for acoustic noise associated with rock installation operations to interfere with acoustic position references should be minimised by appropriate placement of sensors.

Power for the position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103 offers the following operational considerations for rock placement vessels and must be read in conjunction with IMCA M103 in its entirety.

A16-3 Operational Guidance

A16-3.1 Operational Considerations

The following should be considered when planning DP operations:

- *Rock placement operations generally have a very short time to terminate. Providing the vessel and fall pipe ROV are clear of adjacent structures then a loss of DP control leading to an inability to maintain position* *may not have serious consequences. Recovery of the fall pipe may be protracted but can usually be achieved;*

- *In low risk, open water operations it may not be necessary for the DP system to be configured to be fault-tolerant (TAM);*
- *In open water operations the vessel will generally be able to adopt a heading to minimise vessel motions or thruster load;*
- *DPOs should understand the effects of significant changes in draught on the DP control system;*
- *The effects of currents in the water column between the vessel and the seabed installation site may impose different forces on the fall pipe at different depths; these forces may impact vessel position keeping, or with flexible fall pipes may result in the vessel being significantly offset from the position of the fall pipe discharge. Significant current sheer forces may result in distortions in a flexible fall pipe causing blockages of rock materials;*
- *Environmental limits may be dictated by vessel motion rather than position keeping capability;*
- *When rock placement is required in close proximity to a surface obstruction then techniques should be adopted that allow a safe separation to be maintained between the vessel and the obstruction; depending on the water depth, lateral chutes or flexible fall pipes may allow the vessel to maintain an offset from the installation location. Vessel approach closer than 10m to the obstruction should be avoided, except where suitable mitigating measurers determined by risk assessment have been implemented (such as installation of fenders).*

IMCA M103 offers the following operational planning for rock placement vessels and must be read in conjunction with IMCA M103 in its entirety.

Operational Planning

Where a loss in vessel position poses a hazard to personnel, to the vessel or to the environment the following should be documented (where appropriate):

- *Risk assessment of the loss of vessel position;*
- *Configuration for the critical activity mode of operation (CAM) giving guidance to the crew for the most robust fault-tolerant configuration of DP critical systems. Task appropriate configuration (TAM) for operations where an inability to maintain position may constitute a lesser risk;*
- *Activity-specific operational guidelines (ASOG) defining the operational, environmental and equipment performance limits that apply during operations, including details of actions to be taken in the event of any of the defined limits being exceeded*

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

A dredger is a type of ship or barge equipped with machinery and equipment used to remove sediment and other material from the bottom of a body of water, such as a river, harbour, or canal. Dredgers are used to maintain the depth of waterways and prevent them from silting up, as well as to create new channels, basins, or land.

Dredgers typically have a hull with a large, open deck area and are equipped with a cutter head, suction pipes, and pumps. The cutter head is used to loosen and break up the sediment, which is then sucked up through the suction pipes and pumped to the deck, where it is stored and eventually disposed of.

Dredgers can be classified into several types, including trailing suction hopper dredgers, cutter suction dredgers, backhoe dredgers, and grab dredgers, based on the type of dredging equipment they use.

Dredging is an important operation in a variety of industries, including maritime, construction, and environmental management. It is used to ensure the safe and efficient navigation of ships, to create new land for development, and to restore and protect aquatic habitats. The design and specifications of dredgers vary depending on the specific needs of the dredging operation they support.

Trailing suction hopper dredgers are a type of dredger that uses a suction pipe and a hopper to remove sediment from the bottom of a body of water. The following outlines how trailing suction hopper dredgers work:

1. Dredging: The dredger moves along the body of water with a long suction pipe extending from the stern of the vessel into the water. The pipe is used to suck up the sediment from the bottom of the water and into the hopper, which is a large, open hold located on the deck of the vessel.
2. Cutting: A cutter head is located at the end of the suction pipe and is used to break up the sediment and make it easier to suck up into the hopper. The cutter head is also used to create an opening in the sediment, allowing the suction pipe to reach deeper into the water.
3. Suction: Once the sediment has been broken up by the cutter head, it is sucked up into the hopper through the suction pipe. The hopper holds the sediment until it can be disposed of.
4. Discharging: The hopper can be emptied by opening a gate on the bottom of the vessel, allowing the sediment to be discharged into a barge or dumped on the shore. The hopper can also be emptied while the dredger is at anchor, allowing the sediment to be discharged into the water.
5. Repeat: The process is repeated as the dredger moves along the body of water, removing sediment and maintaining the desired depth of the waterway.

Trailing suction hopper dredgers are used for a variety of dredging operations, including the maintenance of navigational channels, the creation of new land, and the restoration of aquatic habitats. They are particularly useful for dredging operations that require the removal of large quantities of sediment, as the hopper allows the sediment to be stored until it can be disposed of.

IMCA M103 offers a whole section on the *A17-1 Industrial Mission* of ***Dredging Vessels.*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- *A17-1 Industrial Mission*
- *A17-1.1 Description and Role*
- *A17-2 Design Guidance*
- *A17-2.1 Design Considerations*
- *A17-2.2 DP Capability*
- *A17-2.3 Control Systems*
- *A17-2.4 Reference Systems and Sensors*

- *A17-2.5 Power Systems*
- *A17-3.1 Operational Guidance*
- *A17-3.2 Operational Planning*
- *A17-3.3 Communications*
- *A17-3.4 DP Alert Status*
- *A17-3.5 Responsibilities*

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103 offers the following operational considerations for dredgers and must be read in conjunction with IMCA M103 in its entirety.

The following should be considered when planning DP operations:

Depending on the technique adopted, dredging is usually characterised by a short time to terminate; dredging equipment can be lifted clear of the seabed and the vessel can move to a safe location immediately;

Depending on the effectiveness of heave compensation equipment, environmental limits may be lower for equipment deployment and recovery than they are for dredging operations;

Vessel motions may adversely affect dredging accuracy and cause damage to the seabed if dredging tools are rigidly connected to the vessel. Heave compensation may not be fully effective as mitigation; the DPO should be aware of how a change of heading and/or track will affect heave, roll and heel;

Significant propulsion power may be required to overcome dredging forces. Dredging forces will tend to dampen position excursions, but may reduce the vessel's ability to maintain a constant dredging speed;

Choice of heading may be restricted depending on the dredging technique employed;

Very shallow water activities may be subject to stricter environmental and vessel motion limits than those for deeper water;

Under-keel clearance requires careful consideration in shallow water due to the risks to thrusters and cooling systems. Thruster efficiency may be reduced and vessel pitching and rolling may reduce under-keel clearance significantly;

The vessel may experience rapid changes in dredging forces acting on the vessel during constant speed dredging due to the changing nature of the seabed resulting in thruster power demand fluctuations;

Accurate positioning of dredging tools on the seabed may be difficult if the seabed is not of uniform density or is uneven. The vessel may be required to rapidly adjust track to compensate for deflection in position of the dredging tool. These considerations are important when operating close to surface and seabed infrastructure;

The master and each DPO should understand the principles and operation of any special features of the DP control system. They should be aware of the likely forces exerted on the vessel by the dredging operation and the procedure for emergency termination of operations.

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water	Close to a structure
DGNSS	DGNSS
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for dredgers and must be read in conjunction with IMCA M103 in its entirety.

A17-2.4 Reference Systems and Sensors

At least three independent position reference systems should be in use for IMO equipment class 2 or 3 designs where position keeping is safety-critical, employing at least two different measurement principles. Power for the position references in fault tolerant DP systems should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

Where dredging is conducted in close proximity to offshore surface structures then at least one relative reference should be in use with the adjacent structure. Where relative reference systems are susceptible to interference (for example from cranes, structures and environmental conditions) then the potential for loss of position references should be risk assessed and suitable alternatives provided.

In shallow water noise, strong currents and suspended particles in the water column may cause interference to seabed reference systems. Acoustic systems are vulnerable to interference from noise associated with the dredging operation, however they may be used to monitor the position of subsea equipment.

In open water locations where the risks associated with an inability to maintain position are low there may be a reliance on satellite based position references; availability and diversity of position references may be limited in open water.

Sensors providing data relating to horizontal dredging forces acting on the vessel may be interfaced to the DP control system. Where loss of such data may impact position keeping performance, sensors should be robust, accurate and reliable and consideration should be given to providing redundancy. Where reliability or fail safe conditions cannot be demonstrated, then manual input or force inputs based on theoretical calculation may be considered.

SOV SERVICE OPERATIONS VESSELS

MTS issued a Paper regarding Wind Turbine Support Vessels

GENERAL DESCRIPTION / CONSIDERATIONS - SPECIFIC TO MISSION

A service operations vessel (SOV) is a type of ship or boat used in the offshore wind industry to provide support and maintenance services to wind turbines and other offshore structures. The main function of an SOV is to transport personnel, equipment, and supplies between the shore and the offshore site, as well as to provide accommodation and other support services to the maintenance crew while they are working offshore.

SOVs are typically equipped with a range of facilities and equipment, including:

1. Accommodation: The SOV typically has a large deck area with cabins and facilities for crew members, including bedrooms, bathrooms, kitchens, and recreation areas.
2. Workspace: The SOV also has a workshop or maintenance area for servicing and repairing wind turbines and other offshore equipment.
3. Cargo handling: The SOV has cargo handling equipment, such as cranes, winches, and hoists, to load and unload equipment, supplies, and personnel.
4. Safety equipment: The SOV is equipped with safety equipment, such as life rafts, life jackets, and firefighting equipment, to ensure the safety of the crew and passengers.
5. Communication equipment: The SOV has communication equipment, such as radios, telephones, and satellite systems, to allow for communication between the crew and the shore.

The design and specifications of SOVs vary depending on the specific needs of the offshore wind operation they support, as well as the size and complexity of the offshore structures they serve. SOVs play a critical role in the offshore wind industry by providing the maintenance and support services necessary to keep wind turbines and other offshore structures operating efficiently and safely.

IMCA M103 offers a whole section on the *A18-1 Industrial Mission* of ***Service Operations Vessels (SOV).*** While we cannot reproduce the section here in its entirety, we do recommend you read it in full if you work on or with an SOV. The section headings are as follows:

- A18-1 Industrial Mission
- A18-1.1 Description and Role
- A18-2 Design Guidance
- A18-2.1 Design Considerations
- A18-2.2 DP Capability
- A18-2.3 Control Systems
- A18-2.4 Reference Systems and Sensors
- A18-2.5 Power Systems
- A18-3.1 Operational Guidance
- A18-3.2 Operational Considerations
- A18-3.3 Communications
- A6-3.4 DP Alert Status
- A18-3.5 Gangway Status
- A18-3.6 Responsibilities

REFERENCE SYSTEMS & SENSORS - SPECIFIC TO MISSION

See also DP Position Reference Systems and Sensors and Reference Systems and Sensors (general considerations from a mission perspective)

Open water (standby)	Close to a structure
DGNSS	DGNSS
Relative GNSS	Relative GNSS
	Laser
	Radar

IMCA M103 offers the following guidance for position reference systems and sensors for SOVs and must be read in conjunction with IMCA M103 in its entirety.

A18-2.4 Reference Systems and Sensors

At least three independent position reference systems using a minimum of two measurement principles should be in use when in close proximity to a structure.

At least three independent heading reference sensors for the DP system should be provided.

When working in close proximity to fixed structures then at least one relative position reference system should be used. If the adjacent structure is floating and a relative separation needs to be maintained, then at least two of the position references used should be relative systems. Caution needs to be exercised when using a mix of absolute and relative position references when the target structure is able to move. The DP control system may require appropriate modes and features to be able to maintain position in a stable and reliable manner.

Reference systems should be selected so as to minimise possible interference during gangway and crane operations.

Power for position references should be supplied from different redundancy groups to prevent the worst case failure resulting in the loss of all position references.

Lessons learned SOV vessels

This case study demonstrates the importance of careful selection and planning in the use of position reference sensors and the potential consequences therein.

DP2 Service Operations Vessel (SOV) DP Incident

OPERATIONAL CONSIDERATIONS & PLANNING - SPECIFIC TO MISSION

IMCA M103 offers the following operational considerations for dredgers and must be read in conjunction with IMCA M103 in its entirety.

A6-3.5 Gangway Status

Independent of any DP alert, an alert system should be fitted for the gangway crossing. The gangway operation manual should provide advice covering the action to be taken on the specific gangway, but in general:

- *Green status lights each end of the gangway to indicate 'safe to cross';*

- *Red lights each end of the gangway and an audible alarm to indicate 'unsafe to cross', persons on the gangway should act as required by the gangway specific emergency procedures.*

There might be a number of options for activating the gangway alert system, including:

- *audio/radio warning from bridge to operator;*
- *DP performance traffic light visible to gangway operator;*
- *gangway MRU programmed to judge DP performance based on envelope size and accelerations;*
- *DP integration allowing DPO to directly influence the traffic light.*

Where it is possible to execute a change of position or heading without disconnecting the gangway then the gangway alert system should indicate a red light status. Additionally, the DPO is to ensure that there are no persons using the gangway before any change in centre of rotation, DP position or heading is implemented.

A6-3. 6 Responsibilities

The master and windfarm co-ordinator should co-operate closely in responding to emergency situations. Their respective authority and responsibilities should be agreed and understood by both parties. The master has authority over the SOV but needs to consider the requirements of the co-ordinator and the safety of personnel in the windfarm.

The vessel master is responsible for the safety of the vessel and all personnel on board or working from it. This includes the authority to forbid the start or order the suspension of personnel transfer operations, including in conditions where operational limits defined in ASOGs have not been exceeded.

The DPO is responsible for ensuring that the DP system is configured as specified in the CAM/TAM and for monitoring vessel position and that the vessel operates within limits defined in the ASOG. The DPO is responsible for changing the DP alert status with reference to the ASOG without delay should this become necessary and for carrying out the associated actions. They have the authority to suspend personnel transfer operations if they consider this to be necessary for the safety of the vessel, environment or personnel.

SPACE FOR NOTES

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