TECHNICAL AND OPERATIONAL GUIDANCE (TECHOP)

TECHOP_ODP_14_(D)
(PRS AND DPCS HANDLING OF PRS)

SEPTEMBER 2017

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SUMMARY

This MTS TECHOP provides general guidance on PRSs and the handling of the PRS by the DPCS. It is intended to enhance awareness of issues that have led to DP station keeping incidents and good practices to mitigate against such potential.

The TECHOP promotes ‘systems thinking’ application to PRSs and handling of PRS by DPCS as a means to achieve incident free DP operations.

The TECHOP is not written with the objective of providing explicit solutions nor is it intended to be a specification. It is written in a manner that facilitates outlining the functional objectives.

The TECHOP restricts itself to address systems architecture as commonly used in DP marine applications it is not intended to be prescriptive to this architecture nor restrict adoption of other system architectures

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ABBREVIATIONS & DEFINITONS

‘Systems Thinking’	Systems Thinking as defined in this document is to approach PRSs and DPCSs with a combination of siloed approaches and holistic impacts with the view to predictably deliver incident free DP operations and prevent unintended consequences.
ABS	American Bureau of Shipping
DNV	Det Norske Veritas
DP	Dynamic Positioning
DPCS	Dynamic Positioning Control Systems
DPO	Dynamic Positioning Operator
EPE	Estimated Position Error
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistema
GNSS	Global Navigation Satellite System
HMI	Human Machine Interface
IMCA	International Marine Contractors Association
LBL	Long Base Line
MOC	Management of Change
MSF	Marine Safety Forum
MTS	Marine Technology Society
NMEA	National Marine Electronics Association
OEM	Original Equipment Manufacturer
OSV	Offshore Supply Vessel
PRS	Position Reference System
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radio Frequency
ROV	Remotely Operated Vehicle
SIMOPS	Simultaneous Operations
UPS	Uninterruptable Power Supply
USBL	Ultra-Short Base Line
USCG	United States Coast Guard
VRU	Vertical Reference Unit

1 INTRODUCTION - TECHOP (TECHNICAL AND OPERATIONAL GUIDANCE)

1.1 PREAMBLE

1.1.1 Guidance documents on DP, Design and Operations, were published by the MTS DP Technical Committee in 2011 and 2010, subsequent engagement has occurred with:

- Classification Societies (DNV, ABS).
- United States Coast Guard (USCG).
- Marine Safety Forum (MSF).

1.1.2 Feedback has also been received through the comments section provided in the MTS DP Technical Committee Website.

1.1.3 It became apparent that a mechanism needed to be developed and implemented to address the following in a pragmatic manner.

- Feedback provided by the various stakeholders.
- Additional information and guidance that the MTS DP Technical Committee wished to provide.
- Means to facilitate revisions to the documents and communication of the same to the various stakeholders.

1.1.4 The use of Technical and Operations Guidance Notes (TECHOP) was deemed to be a suitable vehicle to address the above. These TECHOP notes will be in two categories.

- TECHOP_ODP.
- TECHOP_GEN.

1.2 TECHOP_ODP

1.2.1 Technical Guidance Notes provided to address guidance contained within the Operations, Design or People documents will be contained within this category.

1.2.2 The TECHOP will be identified by the following:

1.2.3 TECHOP_ODP_SNO_CATEGORY (DESIGN (D), OPERATIONS (O), PEOPLE (P))

- EG 1 TECHOP_ODP_01_(O)_(HIGH LEVEL PHILOSOPHY).
- EG 2 TECHOP_ODP_02_(D)_(BLACKOUT RECOVERY).

1.3 TECHOP_GEN

1.3.1 MTS DP TECHNICAL COMMITTEE intends to publish topical white papers. These topical white papers will be identified by the following:

TECHOP_GEN_SNO_DESCRIPTION.

- EG 1 TECHOP_GEN_01-WHITE PAPER ON DP INCIDENTS.
- EG 2 TECHOP_GEN_02-WHITE PAPER ON ANNUAL DP TRIALS.

1.4 MTS DP GUIDANCE REVISION METHODOLOGY

1.4.1 TECHOPs as described above will be published as relevant and appropriate. These TECHOPs will be written in a manner that will facilitate them to be used as standalone documents.

1.4.2 Subsequent revisions of the MTS Guidance documents will review the published TECHOPs and incorporate as appropriate.

1.4.3 Communications with stakeholders will be established as appropriate to ensure that they are notified of intended revisions. Stakeholders will be provided with the opportunity to participate in the review process and invited to be part of the review team as appropriate.

2 SCOPE AND IMPACT OF THIS TECHOP

2.1 PREAMBLE

2.1.1 This TECHOP provides general high level guidance on position reference sensors, sensors and handling of the same by the DP Control system.

2.1.2 This TECHOP is not intended to be a specification. It outlines the functional objectives that are expected to be achieved by both PRSs and DPCSs in order to achieve predictable delivery of incident free DP operations.

2.1.3 The target audience for this TECHOP encompasses all stakeholders involved in the delivery of DP operations. As examples:

1. PRS and DPCS vendors.
2. Shipyards.
3. Owners & Managers of DP vessels.
4. Assurance organisations.
5. Classification societies.
6. Vessel management and operations teams.
7. Industrial mission project execution teams.

2.1.4 Lessons learned from review of loss of position incidents have been summarized within the guidance documents published by the MTS DP Committee (Design, Operations and Development of People and various TECHOPS). A similar approach has been taken in this TECHOP.

2.1.5 One of the key lessons learned was that DP Equipment Class requirements needed to be supplemented with a focus on the Industrial Mission. This focus on the Industrial Mission, brought to light the need to understand the activities being performed as part of the Industrial Mission and the consequences of the loss of position.

2.1.6 Achieving the highest level of station keeping integrity on DP is influenced by what is referred to in the MTS Guidance documents as the seven pillars:

1. Autonomy.
2. Independence.
3. Segregation.
4. Differentiation.
5. Fault tolerance.
6. Fault resistance.
7. Fault ride through.

Note: *The definition of the terms autonomy, independence and segregation has been adapted for PRSs as used in this TECHOP in 5.2.7.*

2.1.7 Paying attention to the above attributes and disciplined application to power plant design has delivered demonstrable improvements in reducing loss of position events associated with power and propulsion system failures.

2.1.8 The demonstrable improvements were significantly influenced by a conscious application of a ‘Design to Test’ philosophy.

2.1.9 Extensive verification by testing is essential to demonstrate and build confidence. The testing aspect should be omnipresent and applied throughout the design, development and operational stages.

2.1.10 This TECHOP aspires to achieve similar reduction in loss of position events associated with PRS and handling of PRS by DPCS.

2.1.11 The suitability/acceptability of a DP vessel to undertake its Industrial Mission is determined by a multitude of Stakeholders (e.g., Owners, Classification Societies, Statutory authorities, Charterer's etc.). Nothing in this TECHOP is intended to exclude or endorse decisions on the suitability of a vessel.

2.1.12 It is emphasized that Classification Societies stipulate requirements to be met in order to be granted Class Notations. Other Stakeholders may impose additional requirements (e.g. Contractual, Statutory). Verification requirements of all such stakeholders must be unambiguously understood in order to meet desired expectations of station keeping integrity.

2.2 SCOPE

2.2.1 MTS TECHOP_ODP_14_(D)_(PRS, DPCS and Handling of PRS) provides information on:

- Application of the seven pillars to PRSs.
- Functional objectives to be achieved (PRS & DPCS).
- The emphasis and importance of protective functions and verification and validation of the same.
- The significance of following OEM guidance (location of equipment, operational parameters).
- The need to automate functions to the extent practical to alleviate the cognitive burden and response requirements of the DPO.
- Leveraging the advancement and development of technology to shed the burden of legacy impositions / constraints.
- Leverage OEM vendor expertise to analyse PRS performance data and proactively prevent failures / incidents.

2.3 IMPACT ON PUBLISHED GUIDANCE

2.3.1 This TECHOP provides supplementary information to that provided in Section 9.2.5 of the 'MTS DP Vessel Design Philosophy Guidelines', Part II, 2012 but does not alter or invalidate the information provided in that section.

2.4 ACKNOWLEDGEMENTS

2.4.1 The DP Committee of the Marine Technology Society greatly appreciates the contribution of the following individuals to the preparation of this TECHOP.

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3 CASE FOR ACTION

3.1 IMO MSC 645 & 1580 ‘GUIDELINES FOR VESSELS (AND UNITS) WITH DYNAMIC POSITIONING SYSTEMS’

3.1.1 Section 3.4.3.1 ‘Position reference system’ states:
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.

3.1.2 This TECHOP provides guidance on achieving the above objective.

3.2 PRS AND DPCS HANDLING OF PRS AS CAUSAL AND CONTRIBUTORY FACTORS IN DP INCIDENTS - INDUSTRY EXPERIENCE

3.2.1 The IMCA Station Keeping Incident Reporting Scheme (1) is a voluntary and the largest record of station keeping incidents. It provides useful information to members but is not a comprehensive record of DP incidents and their causes. To supplement this, information from the DP vessel owning / operating community has been included in the discussion below.

3.2.2 The following anonymous examples give a brief outline of the DP community’s experience of failure effects associated with PRS and DPCS handling of PRS.

- 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).

3.3 THEMES ARISING FROM REVIEW OF ABOVE CAUSAL AND CONTRIBUTORY FACTORS

3.3.1 Review of the above incidents resulted in the identification of themes. The approach fostered by this TECHOP is to adopt a system's engineering approach to addressing these themes.

3.3.2 Consultation with the PRS, DPCS, vessel owning / operating and assurance organization, communities resulted in the consensus that such an approach could yield a significant reduction in the number of loss of position incidents attributed to PRS and DPCS.

3.3.3 The issues identified as causal and contributory factors have been grouped into the following themes.

1. OEM installation recommendations.
2. PRS provided information (position data, integrity checks and quality indicators).
3. DP control system handling of PRSs.
4. External Interfaces to PRSs and DPCS not essential for DP station keeping.
5. Operator configurable settings (PRS and DPCS).
6. Validation and verification activities (PRS and DPCS).

3.3.4 The review also revealed that a system's engineering approach had to be adopted to provide the necessary confidence in the integrity of PRSs and DPCS handling of PRSs.

3.3.5 The basis to build such confidence depends on taking a holistic view of the system as a whole and consciously designing the physical and logical interfaces in a manner that makes it agnostic to the choice of vendors.

3.3.6 Historically, there has been a tendency to treat sensors as disassociated from the position reference sensors. Adopting a systems approach and aligning with the redundancy concept to the extent practical will deliver better outcome.

3.3.7 The choice of PRSs and the extent to which redundancy requirements are applied is dependent on the industrial mission and the consequence of loss of position.

3.3.8 The integrity of the solution is dependent on utilizing the appropriate equipment in the appropriate quantities. (Example – dual frequency GNSS receivers versus single frequency receivers, prisms as reflective targets versus other reflective surfaces for laser based systems, multiple laser targets and microwave transponders versus single laser targets and microwave transponders, five transponder arrays versus three transponder arrays in non-inertially enhanced LBL systems etc.)

3.3.9 All PRSs irrespective of measurement principles should have a disciplined approach to addressing:

- Line of sight.
- Interference.
- A common reference point (all offset measurements for transducers, GNSS antenna, scanner heads, taut wire gimbals etc. should be measured relative to the common reference point.)

3.3.10 Slow drift of PRSs and detection of the same continues to be a challenge. Mitigation strategies include balancing out the number of PRSs in use based on different principles to minimize potential for rejection of good sensors by slow drifting sensors. (Example – 2 GNSSs plus two Acoustic PRSs versus two GNSS and one Acoustic PRS. No more than two GNSSs should be used in conjunction with a single Acoustic PRS).

3.3.11 It should be noted that DPCS models are susceptible to inaccuracies in heavy weather conditions. The use of a velocity measurement may be a solution to this issue in bad weather conditions.

3.3.12 Heading data provided by mechanical gyros when used by PRSs and DPCSs is a known source of errors and potential position keeping degradation.

3.3.13 Integration of position reference sensors with inertial navigation systems results in improved performance of the combined position reference system.

3.3.14 In the case of PRS aided inertial systems, loss of inertial function should not result in loss of the PRS. Both the PRS and the Inertial system should initiate an alarm when they are no longer capable of providing valid positioning data. Loss of aiding updates to the integrated solution beyond a vendor defined time limit should be alarmed.

3.3.15 Use of high accuracy GNSS services allows improved fault analysis even if such accuracy is not essential for station keeping performance.

4 GOLDEN RULES FOR ALL PRS

4.1 GENERAL

4.1.1 The section below lists practices that are recommended for all PRS.

4.2 RECOMMENDED PRACTICE

4.2.1 There is abundant industry guidance recommending against the dual use of PRSs for survey and positioning. This is a result of incidents being caused where configurations specific to survey have not been restored to configurations required for positioning. Where such dual use is unavoidable processes / controls should be in place to avoid unintended consequences. Effective methods of preventing fault transfer should be used such as galvanic isolation.

4.2.2 The design of PRSs should strive to achieve the shortest reboot time that is practical. This philosophy should be embedded in systems thinking for all system comprising the DP system.

4.2.3 Data provided by PRSs to the DPCS should be devoid of ‘smoothing’ and with as little latency as practical. It is accepted that the PRS vendor will undertake ‘filtering’ to the extent necessary to provide accurate and reliable data.

Smoothing may be undertaken for display purposes only at the PRS vendor HMI.
Note: For the purposes of this discussion:

- Smoothing is the principle of removing certain frequencies from the signal above a defined limit.
- Filtering refers to the practice of applying predicative filters for removing faulty data from the position information.
- Adequate transparency should be provided on strategies addressing latency and filtering and smoothing and lever arm compensation. Lack of a common understanding between PRS vendors, DPCS vendors and vessel management teams could result in consequences leading to a loss of position during DP operations.

4.2.4 Repeating the last received position data point from a PRS with a low update rate at a higher update rate in order to artificially balance the weight applied to a low update rate PRS (fill-ins) should be avoided. Such a practice has known to result in degradation of the DPCS model and has contributed to loss of position incidents.

4.2.5 A PRS should not knowingly output invalid position data.

4.2.6 A PRS should be able to report itself as faulty, when it is able to determine this, and the DPCS should take appropriate action on this indication.

4.2.7 Accuracy should be reported against a standard accuracy (Example – A standard deviation of 1 σ / 2 σ)

Note: 1σ *should be the default. Justifications for deviations, if any, should be documented to provided transparency.*

4.2.8 There should be an alignment between the PRSs data reporting protocols and the DPCS requirements. Transparency is essential for the validation and verification processes.

4.2.9 Impacts of obsolescence (hardware and software) should be recognized and effectively managed.

4.2.10 A system should be in place to ensure that vendor’s alerts (Technical and Safety) are diligently implemented.

4.2.11 AN auditable system should be in place to ensure that impacts of firmware changes on functionality and performance are identified, documented and addressed appropriately. This system should apply to PRS vendors and their external suppliers.

4.2.12 It is essential to apply robust MOC processes to any changes in PRSs and DPCSs.

4.2.13 Systems design thinking should be extended to PRS HMIs to provide alarms based on watch circles. Many PRSs have such capability which should be utilized to provide an additional means of verification independent of the DPCS.

4.2.14 Predictable outcomes of incident free DP station keeping is significantly impacted by PRSs and handling of same by DPCSs. All four themes, (design, operations, people and process) need to be addressed. The need for effective training focused on PRSs should not be underestimated.

5 PHILOSOPHY TO ADDRESS THEMES IDENTIFIED IN ‘CASE FOR ACTION’

5.1 ADAPTING PROVEN APPROACHES IN IMPROVING DP POWER AND PROPULSION INTEGRITY AND PREDICTABILITY

5.1.1 Chronic integrity and predictability issues in DP power and propulsion systems have been addressed by consciously embedding attention to the seven pillars referenced in Section 2.1.6.

5.1.2 This has resulted in a demonstrable reduction of loss of position incidents attributed to power and propulsion issues.

5.1.3 The development process for this TECHOP included reviews of lessons learned and applicability of proven approaches in reduction of loss of position incidents.

5.1.4 The above activity led to the conclusion that applicability of the proven Seven Pillars approach to PRSs and handling of PRSs by DPCS is appropriate.

5.2 DISCUSSION ON SIMILARITIES AND DIFFERENCES OF PRS AND DPCS HANDLING OF PRS IN COMPARISON WITH POWER AND PROPULSION

5.2.1 Figure 5-1 shows the redundancy design intent for a typical DP system power plant divided into three redundant equipment groups. Active redundancy is used in the design of DP power plant and it is relatively easy to reduce the number of cross connections and provide each equipment group with the necessary autonomy, independence and segregation.

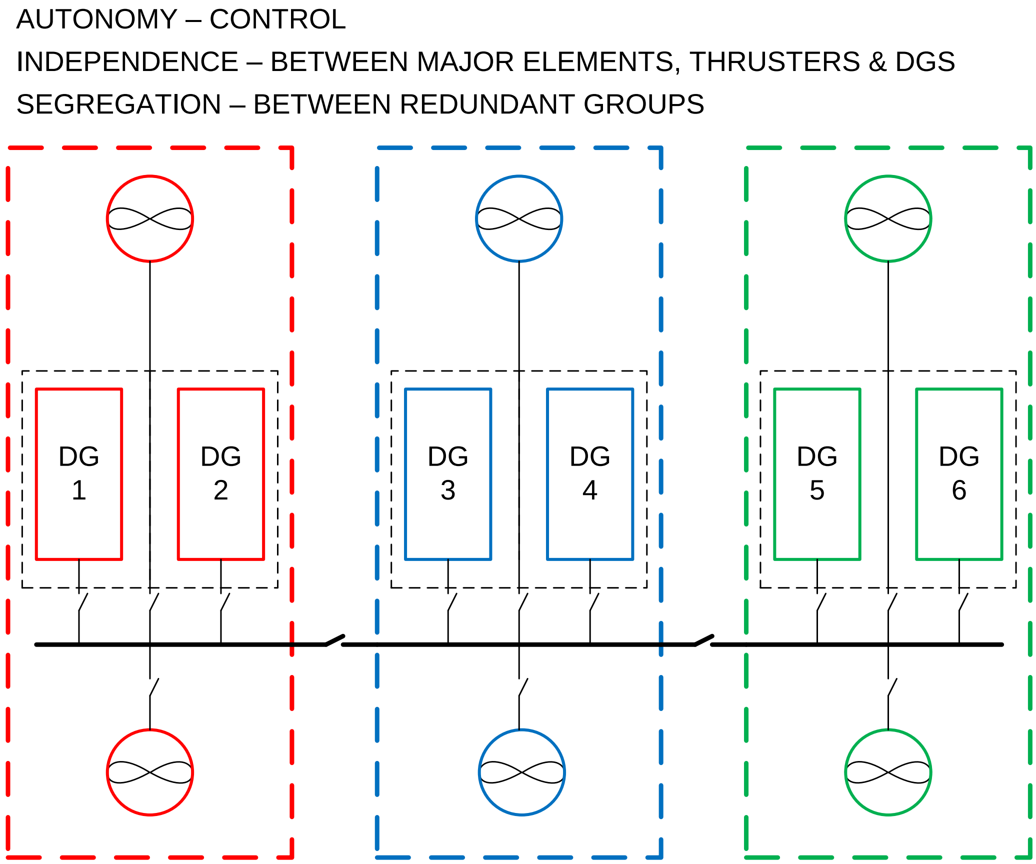

Figure 5-1 **Redundancy Design Intent in DP Power Plant**

5.2.2 Figure 5-2 shows the redundancy design intent for a typical DP control system. There are often a larger number of cross connections and redundancy is based on hot-standby. Thus, there is greater reliance on fault tolerance, fault resistance and fault ride through.

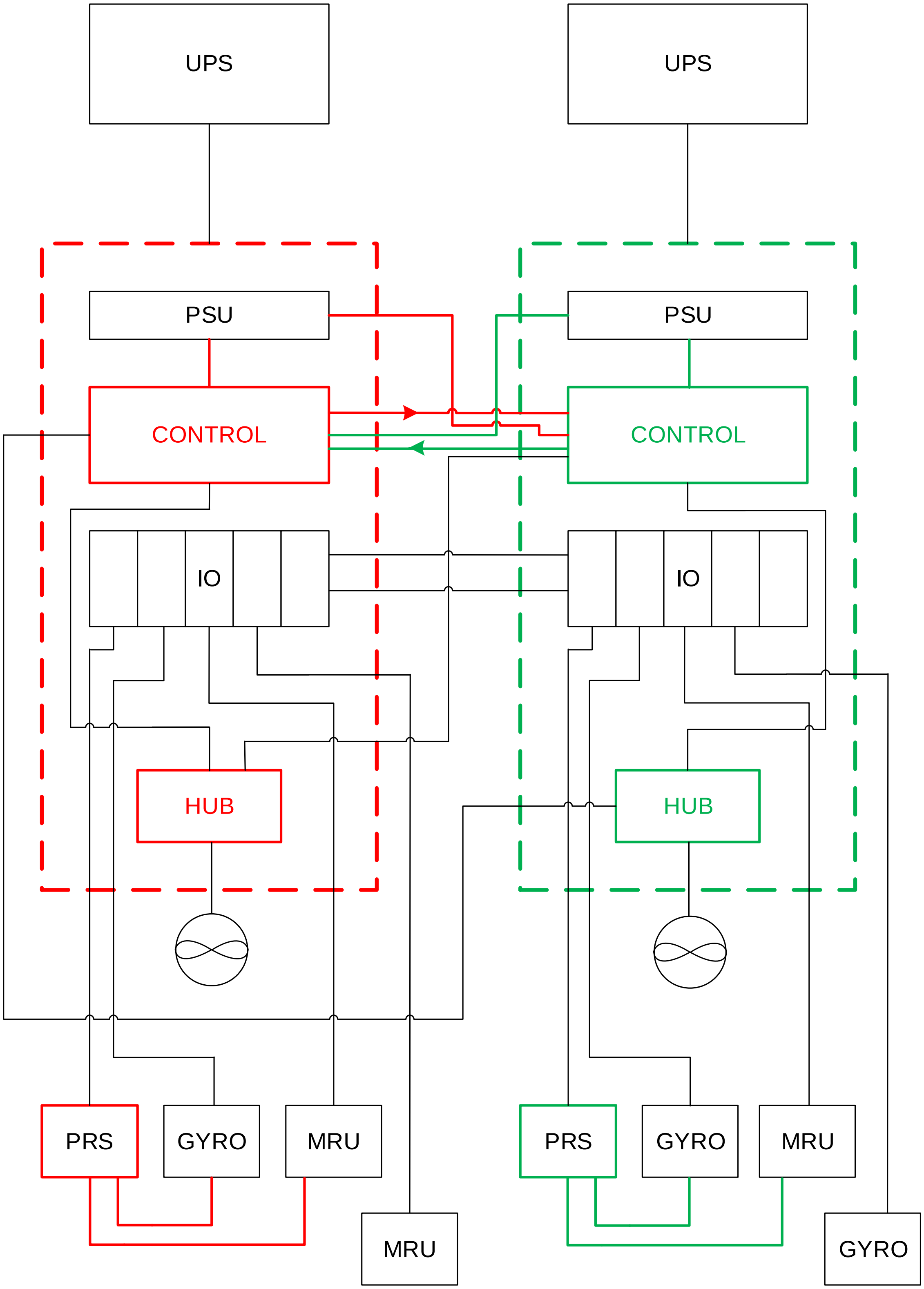

Figure 5-2 Redundancy Design Intent In DPCS

5.2.3 From the block diagram depicting the power and propulsion redundancy concept it is apparent that defense of the attributes of autonomy, independence and segregation is more readily achievable.

5.2.4 Where attributes of autonomy, independence and segregation are compromised the burden of proving the attributes of fault tolerance, fault resistance and fault ride through is greater. This usually involves a greater validation and verification effort of the protective functions.

5.2.5 Attention to the attributes described in 5.2.4 and application in power and propulsion systems has resulted in predictable delivery if incident free DP operations.

5.2.6 A comparison between the block diagram for power and propulsion redundancy concepts and that for DPCS and PRSs makes it readily apparent that the attributes of autonomy, independence and segregation are compromised. This is an artefact of the desired functionality of the DPCS by virtue of it being a common point spanning equipment groups intended to provide redundancy.

5.2.7 The definitions of the seven pillars developed for power and propulsion have been adapted to PRSs and defined in Tables 5-1, 5-2 and 5-3. The adaptations are specific to principles of the PRS. Note: Example – Autonomy, Independence and segregation for PRSs are defined as follows:

- **Autonomy** – A PRS should become available in its expected operational state with no intervention from the operator.
- **Independence** – A PRS should have everything it requires to provide position information to the DPCS – Not be subject to a common cause of failure with other PRS.
- **Segregation** – PRS of the same principle should be divided into separate groups to reduce the risk of losing two or more PRS of the same principle to the effects of internal and external common cause failures. Attention should be given to retaining a mix of principles after worst case failure of PRS.

5.2.8 Thus, it is essential that protective functions within PRSs and DPCSs are expected to be comprehensive. The verification and validation will have to be comprehensive. A systems approach will need to be adopted.

5.2.9 A design and ‘build-to-test’ philosophy is necessary due to the dependence on comprehensive protective functions to deliver integrity and predictability.

5.2.10 It is acknowledged that interface protocols between PRS and DPCS currently in use are an evolution of standards developed for general applications in the marine industry. This should not preclude the development of interface protocols tailored for DP applications. Such development when pursued should incorporate lessons learned, be an open standard, and facilitate future expansion and integration of equipment while being agnostic to equipment providers.

5.2.11 The terms ‘quality’ and ‘integrity’ are used frequently throughout this TECHOP in relation to metrics that could be passed from PRS to DPCS

- Quality refers to a ‘performance indicator’.
- Integrity refers to a ‘reliability indicator’.

Table 5-1 GNSS Systems View of PRS

		Attributes (7 Pillars)						
		Autonomy	**Independence**	**Segregation**	**Differentiation**	**Fault Tolerance**	**Fault Resistance**	**Fault Ride-Through**
GNSS	**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 start-up • 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: Multi-reference 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

	Attributes (7 Pillars)						
	Autonomy	**Independence**	**Segregation**	**Differentiation**	**Fault Tolerance**	**Fault Resistance**	**Fault Ride-Through**
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						

Table 5-2 Acoustic PRS Systems View of PRS

		Attributes (7 Pillars)						
		Autonomy	**Independence**	**Segregation**	**Differentiation**	**Fault Tolerance**	**Fault Resistance**	**Fault Ride-Through**
ACOUSTIC	**Definition**	• Self-start 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 operation following a single fault (High probability)	• Not susceptible to failures	• Ability to continue providing a valid position output during measurement outages and other disturbances
	Compromised by	• Requirement for operator intervention on start up	• 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
ACOUSTIC	**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						

	Attributes (7 Pillars)						
	Autonomy	**Independence**	**Segregation**	**Differentiation**	**Fault Tolerance**	**Fault Resistance**	**Fault Ride-Through**
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.
	    • 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.
	    • Used as reference when doing transducer alignment
	    • GNSS is needed if an LBL array is being calibrated in geographical coordinates
	• Default position reported is computed position with lever arm compensation applied							

Table 5-3 Relative Systems View of PRS

		Attributes (7 Pillars)						
		Autonomy	**Independence**	**Segregation**	**Differentiation**	**Fault Tolerance**	**Fault Resistance**	**Fault Ride-Through**
TAUT WIRES AND RELATIVE PRS (MICROWAVE LASER ARTEMIS RELATIVE GNSS	**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 failures	• 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)

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="7">Attributes (7 Pillars)</th></tr>
<tr><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>TAUT WIRES
AND
RELATIVE PRS
(MICROWAVE
LASER
ARTEMIS
RELATIVE GNSS</td><td>Remarks</td><td colspan="7">• 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 colspan="2">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>

6 FUNCTIONAL OBJECTIVES OF PRS AND DPCS HANDLING OF PRS DERIVED FROM LESSONS LEARNED

6.1 GENERAL

6.1.1 A systems-thinking approach is essential for effective use of PRSs and associated sensors used for DP station keeping. This 'systems thinking' should encompass PRSs, sensors, DPCS, external interfaces and the DP operator.

6.1.2 It is essential to have a deliberate emphasis on performance attributes, protective functions and detection measures to achieve a robust system with the desired integrity and confidence level.

6.1.3 Lesson's learned revealed, that in some instances, the onset of the incident was contributed by functionality that was not required or essential for undertaking the industrial mission. Such functionality had been provided by the vendor(s) in accordance with the specifications, against their better judgment. Such behavior by vendors was fostered by a desire not to be excluded from competing for the work.

6.1.4 Personnel responsible for developing specifications should be made aware of the above and requirements embedded in the specifications should be rationalized.

6.1.5 The block diagrams used to compare the arrangement of redundancy groups and power and prolusion and PRS and DPCS systems reveals significant differences. See Figure 5-1 and Figure 5-2.

6.1.6 As a result of these differences, the way that the seven pillars are applied to the PRS and DPCS is going to vary from the application to power and propulsion.

6.1.7 The Seven Pillars have been applied to the PRS based on principles of measurement and defined in Table 5-1, Table 5-2 and Table 5-3.

6.1.8 Experience in the application of the Seven Pillars to the power and propulsion systems has shown that it is essential to rationalize the extent and depth to which the attributes are applied to the systems. The objective should be to achieve the integrity desired and not to drive the equipment count unnecessarily.

6.1.9 A similar approach is suggested for application of the Seven Pillars to PRSs and DPCS as described in 6.1.8.

6.2 PRS

6.2.1 Following an interruption and restoration of power a PRS should become available in its expected operational state with no intervention from the operator. If intervention is required this should impose minimum burden on the operator.

6.2.2 The above should be true for any dependencies on external sources / equipment that the PRS requires.

6.2.3 The PRS should provide the data along with quality and integrity metrics.

6.2.4 Data from the PRS to the DPCS should be provided with minimum latency and not subject to processing that compromises the ability of the DPCS to use it in an optimal manner. See Section 4.

6.2.5 A PRS should not knowingly transmit invalid data to a DPCS. See Section 4.

6.2.6 The design of the physical and logical interfaces to the DPCS should be such that there is no misalignment. The objective of this requirement is to achieve optimal use of the information capable of being provided by the PRS. Such physical and logical interfaces should be described in an open standard facilitating integration of equipment agnostic to suppliers.

6.2.7 Adequate transparency of quality and integrity metrics should be provided to facilitate effective validation and verification through the lifecycle. It should be recognized that the opportunity to engineer out flaws is most effective in the design phase.

6.2.8 PRS based on similar measurement principles are vulnerable to common cause failures (within the DP vessel itself). Interference caused by, as examples, proximity of antennas to each other and to RF interference sources, noise generated by the industrial mission being carried out affecting systems (vibration induced by thrusters).

6.2.9 PRS based on the same measurement principles may be vulnerable to external common cause failures associated with the signal transmission path through the sky or sea. Technological developments continue to reduce the risk from these common cause failures but they have not been eliminated entirely and systems engineering approach to the design of PRS and DPCS needs to consider the possibility of occurrence.

6.2.10 DP control systems are usually adept at recognizing abrupt position deviations and rejecting them. Detection and mitigation of slow drift of PRSs continues to be a challenge. There is no single strategy that is effective to deal with the above issue. Experience and learnings from incidents indicates that a combination of approaches is required to reduce vulnerabilities associated with this issue. The approaches vary depending on the industrial mission being undertaken. Examples of such approaches are as follows:

- In general, effort should be put into avoiding too great a reliance on one single technology. However, introducing reference systems that potentially degrade the overall solution should be avoided unless required by the industrial mission (i.e. mixing absolute and relative systems).
- GNSSs as a PRS are prevalent on most DP vessel’s regardless of the industrial mission they are engaged in. Significant improvements can be made by striving to achieve a GNSS solution that is designed to eliminate or at least minimize common mode failures resulting in errors in the position estimate. One such strategy is to leverage diversity in the design of GNSS solutions. Example - diversity in types of GNSS constellations, antenna locations, hardware and software etc.
- Example of once such strategy to deal with slow drift of GNSS is as follows:
  - RAIM and calculation of Estimated Position Error (EPE) to address drift caused by measurement.
  - Use all available correction sources in a multi-reference solution to address drift caused by correction sources.
  - INS integration and dual antenna/INS integration to address issues caused by lever arm compensations and gyro error.
- The systems limitations of Acoustic PRSs (slow update rates) and resultant skewed weighting towards GNSSs can be balanced by the introduction of INS enhancement to Acoustic PRSs. This leads to a more equal balance between GNSS and Hydro-acoustics and increased probability of identifying the failed system. Identification facilitates appropriate intervention by the DPO.
- Where Acoustic PRS are not inertially enhanced, one of the strategies deployed is to utilize the ‘Reduced GPS Weight’ feature in DPCS.
- Having two or more independent Acoustic PRS systems and restricting GNSS inputs to no more than two is another approach.

Note: Impacts and consequences of the use of more than two GNSS inputs, if desired, in conjunction with PRSs based on other principles should be evaluated and documented.

6.3 DPCS

6.3.1 This TECHOP promotes systems thinking and thus reiterates PRS information in the DPCS section due to its relevance.

6.3.2 Each PRS provides an independent measurement of vessel position to the DP system which blends the individual measurements into a single best estimate of vessel position. Individual measurements must have the lowest possible latency because measurement delays will have an adverse effect on DP control.

- Within the PRS, filtering shall not be used to smooth the position estimate.
- PRSs should provide unfiltered data with minimum latency
- Use of predictive filters could be one of the strategies to combine measurements that are received spread out in time, and to exclude erroneous measurements.
- Where possible each PRS should provide a new measurement every second. In the case of PRS with slower update rates, such as deep water acoustic systems without INS, the PRS should not send repeated, duplicate measurements between updates as this has the potential to degrade the mathematical model.

6.3.3 The DPCS typically has a range of protective functions designed to detect and in some cases, reject erroneous PRS and sensor data. These functions operate in different ways:

- By considering the nature of the data being provided. Example – high signal to noise ratio or frozen data.
- By comparing the data from one PRS to that received from others. Example - Median test.
- By comparing the data from the PRS to the position estimate predicted by the mathematical model in the DPCS. Example - Reference prediction test.

6.3.4 Most PRSs are capable of providing additional information other than position data such as quality and integrity metrics. The DP control system could make use of such information if interface protocols are pre-agreed to / aligned with an open standard.

- Conventionally, DPCSs generate their own metrics for Quality and Integrity.
- External metrics provided by the PRSs are not universally used by all DPCS vendors.
- In some cases, this may be a legacy of restrictions imposed by the interface protocols currently in use, lack of deep system knowledge, transparency and alignment.
- External metrics (Example – signal to noise ratio, Integrity etc.) are currently not standardised and thus not easily interpreted without deep knowledge of specific systems.
- Use of error ellipsoids when appropriate has proven to be a successful metric
- Due consideration should be given to evaluating the use of such metrics as part of ‘sanity’ checks.

6.3.5 A PRS can assist the DPCS in its role as a protective function by clearly indicating when it knows itself to be faulty and not knowingly transmitting erroneous data. Transmitting non-data is one strategy for indicating position data is not available without actually ceasing transmission.

6.3.6 It should be noted that DPCS models are susceptible to inaccuracies in heavy weather conditions. The design of DPCS handling of position reference sensor data and protective functions should acknowledge this susceptibility. Prevention of loss of position and predictable behavior of protective functions should be the outcome.

Note: Undesirable outcomes have manifested themselves when the DPCS model has rejected valid position data from PRS. The design of the DPCS should address and mitigate against this potential outcome.

6.4 INTEGRATION OF INERTIAL NAVIGATION SYSTEMS

6.4.1 General

6.4.1.1 This section addresses Inertial Navigation Systems (INS) integration terminology applied to position reference systems.

6.4.1.2 The integration of PRS data with INS data will lead to enhanced positioning performance. A secondary objective could be to extend battery life of acoustic PRSs. Additionally some integrated systems have the ability to provide independent velocity, heave, roll, pitch and heading information.

6.4.1.3 Note: The temptation to extend battery life by pushing acoustic update rates out could result in degradation of INS performance. Bounds should be set to prevent such an outcome.

6.4.1.4 It is not the objective to use a standalone Inertial Navigation System as a PRS. The objective should be PRS (GNSS or Acoustic) aided inertial as a combined PRS solution. In the case where a PRS is coupled to a capable Inertial Navigation Systems the free inertial performance of the capable INS may have value, in a degraded state, as a PRS should the PRS (GNSS or Acoustic) fail to provide aiding data to the INS for an extended period of time. The Free Inertial operational state would be an alarmed state. Note: Free Inertial Navigation is the navigation output of an INS without any aiding input from an external PRS.

6.4.1.5 The architecture by which INS is integrated is varied. This TECHOP does not endorse any particular architecture.

6.4.1.6 Note: System designers are encouraged to evaluate the relative merits of each architecture for their specific application.

6.4.1.7 This TECHOP defines the terminology used to foster consistency in understanding and application.

6.4.2 Loose coupling:

6.4.2.1 The “Position” output from the GNSS or Acoustic system is used to aid, or couple with the INS. A loosely coupled system will reduce noise (USBL smoothing), increase update rate (LBL-INS) and bridge brief gaps in positioning. The performance depends on the GNSS or Acoustic system’s ability to compute both a position and reliable quality metrics for use in weighting within the combined solution.

6.4.3 Tight coupling

6.4.3.1 Tight coupling is a term used to describe systems where the raw GNSS or raw Acoustic observations are used to aid, or couple with the INS. With this level of coupling the integrated solution has full access to the associated low level quality metrics from the specific PRS in their native format and with effectively perfect timing. Tightly coupled solutions are less impacted by the degradation of GNSS or Acoustic systems as the combined solution is not dependent on a standalone position.

6.4.4 Deep coupling

6.4.4.1 Deep coupling is a term used to describe systems in which the GNSS receiver or Acoustic transceiver makes use of information from the INS to enhance their low-level signal processing to significantly improve the signal to noise capability of the combined positioning solution. Note: Systems with deep coupling are not normally seen in DP use at the time of writing this TECHOP.

6.4.5 Close or tight mechanical integration

6.4.5.1 Tight mechanical integration is not to be confused with the chosen method of sensor coupling.

6.4.5.2 Tight mechanical integration means the physical co-location of a PRS with an INS and does not imply the sensor measurements are loosely, tightly or deeply coupled. An example would be the mechanically integrated acoustic-inertial transceivers such as a Gyro USBL.

6.4.5.3 Tight mechanical integration achieves a noticeable improvement in positioning precision compared to mechanically isolated architecture

6.4.5.4 This is achieved by eliminating mechanical instability (Example - the acoustic, transceiver and the heading/attitude device which is a key limiting factor for modern high accuracy USBL systems), a greater control of timing using a common timing source and reducing latency to a minimum.

6.5 OPERATOR INTERFACE

6.5.1 Learnings from incidents have revealed the vulnerabilities caused by imposing cognitive burden on the operator.

6.5.2 The systems design approach and philosophy should strive to minimize unwarranted need for operator intervention. This may result in automating functions when appropriate.

6.5.3 The HMI interfaces need to be designed in a manner that relieves such cognitive burden.

6.5.4 It is acknowledged that the system’s design incorporates the needs of diverse stakeholders. However, the HMI design should incorporate different levels of access based on the needs of the different stakeholders. Adopting this philosophy is expected to relieve the cognitive burdens as well as prevent inadvertent configuration errors contributing to a loss of position.

6.5.5 An example of different levels of access is as follows:

- Level 1 Functionality required for day-to-day use by the operator
- Level 2 Functionality required to configure the system as part of the field arrival / pre-task set-up
- Level 3 Functionality required for maintenance / troubleshooting by onboard maintenance personnel.
- Level 4 Functionality requiring expert OEM support for configuration / troubleshooting.

Note: The above philosophy can be implemented with the use of procedural barriers to limit access in existing HMI interfaces.

6.5.6 PRS vendors should provide comprehensive detail of operator configurable settings. Such detail should include advice on appropriate settings and consequences associated with incorrect settings. Access to configurable settings which if improperly used could result in loss of position should be controlled.

6.5.7 Vessel owners / managers should ensure that vessel specific operating manuals contain details of 6.5.6 as appropriate for the industrial mission.

6.5.8 It is acknowledged such procedural barriers are vulnerable to defeat and a more effective mechanism would be to design them out.

6.5.9 HMI design should consider the use of dashboards to present information in an intuitive format designed for each level of user to reduce cognitive burden.

6.6 OBSOLESCENCE

6.6.1 In the context of this TECHOP, obsolescence is applicable to both hardware and software.

6.6.2 PRSs are more susceptible to obsolescence than DPCSs. Obsolescence is generally triggered by developments in technology, availability of new generation of hardware, disruptions in supply chain (Example – component vendors exiting market either voluntarily or involuntarily etc.) and development of solutions to address issues discovered in service etc.

6.6.3 Obsolescence can result in compatibility issues and affect system integration.

6.6.4 Obsolescence can also result from a vendor’s move to a different hardware / software platform.

6.6.5 Obsolescence created from above has knock-on effects on ability to retain skills and spares to support legacy equipment.

6.6.6 Vessel owners, operators, managers should be aware of the consequences of obsolescence and implement plans to address the same.

6.6.7 Vendor engagement and inputs should be sought in developing effective strategies.

6.6.8 Advice rendered through vendor bulletins (technical bulletins, safety alerts, white papers etc.) should be objectively evaluated and implemented as appropriate. The process of evaluation and basis of decisions should be documented.

6.6.9 The architecture of modern equipment is such that software obsolescence is more likely to be prevalent and manifest itself than hardware.

6.6.10 It is imperative that owners, managers and operators of vessels ensure that the latest version of software appropriate to their installed equipment and industrial mission is being used. Failure to do so may render the vessel susceptible to known failures which have been addressed through software updates.

6.6.11 MOC processes should be applied when obsolescence is being addressed. Such processes should also address timing of activities associated with addressing obsolescence. The goal should be for obsolescence remediation not to result in vessel out of service time.

6.6.12 The potential impacts and consequences of failure to address obsolescence should be clearly evaluated. When considering the continued use of legacy equipment.

6.7 VALIDATION AND VERIFICATION

6.7.1 Validation and verification is the practice of confirming that a particular system has been designed and built in such a way that it achieves its design objectives.

- Validation – The specification achieves the objectives.
- Verification – The unit has been built to the specification.

6.7.2 DP systems of equipment classes 2 & 3 are intended to be single fault tolerant in respect of defined failure criteria. This fault tolerance depends upon redundancy in technical design for both classes and in physical separation for equipment class 3.

6.7.3 In addition to these requirements for fault tolerance, there are specific requirements to maintain a diversity of measurement principles to provide some defence against potential common cause failures.

6.7.4 The DP control system uses several sources of position information. Three sources based on two different principles are used to compare PRSs using median tests as a form of protective function. Such an arrangement also offers a degree of protection against external common cause failures associated with the measurement principle.

6.7.5 The process of verification and validation must consider both hardware and software and should involve a number of different participants and stakeholders:

- Equipment manufacture – Internal processes.
- Classification society – Type approval, plan approval, sea-trials.
- DP assurance organisation – DP FMEA and proving trials and annual DP trials.
- Charterer's representatives – Acceptance trials.

6.7.6 Validation and verification takes place throughout the DP vessel's lifecycle at:

- Manufacture of the PRS.
- Factory Acceptance Test.
- Commissioning of the DP system.
- Sea trials.
- Annual DP trials.
- Periodic class survey – (5 years).
- Post incident - return to work authorisation.

6.7.7 There are three key elements in any fault tolerant system based on redundancy which are:

- Performance.
- Protection.
- Detection.

6.7.8 The processes of validation and verification focus on proving the elements in 6.7.7 are present and that they achieve the design objective. Other verification activities include confirming that the design complies with the various rules and standards to which the equipment is designed such that it is fit for its intended use. In the case of PRS, this activity is intended to ensure the equipment is suitable for the marine environment.

6.7.9 Some parts of the verification process are repeated periodically to ensure the elements of performance protection and detection are still present and have not degraded.

6.7.10 Performance: Initial verification of system performance is carried out by the manufacturer but thereafter, it is checked periodically to see that it is adequate for the task being carried out by testing prior to the DP operation. At this time, any available performance/ quality and integrity indicators are monitored to provide confidence that the system is operating optimally in the prevailing conditions. In the case of PRS with range constraints the PRS is typically used within its maximum and minimum operating range to ensure an adequate margin for degradation associated with phenomena affecting the signal transmission path used for measurement.

6.7.11 Protection and Detection: Protection and detection are related. Protection is required to ensure a fail-safe outcome. Detection is required to indicate a reduction in performance or complete failure of the PRS. Alarms may be required to initiate operator intervention when no automated function exists to address the condition. Failure of one PRS may represent a loss of required redundancy in measurement number and/or principles. The PRS may have internal protective functions intended to ensure it fails-safe and does not output erroneous position data. There are practical limits to the extent that any PRS is able to determine its own health but it is useful to indicate a fault condition when this can be determined with confidence. Verification of these protective functions is largely carried out by the manufacturer although there may be opportunities to test some protective functions and alarms during sea trials and annual DP trials. Each PRS will generally provide a 'Ready' signal to the DPCS either as part of the telegram transmitted to the DPCS or as a digital contact. Tests can be carried out to ensure the PRS or sensor withdraws its 'Ready' status from the DPCS for failure conditions.

Note: In some PRSs, position information is computed from several components (Example – range and bearing) there may be instances where lack of position information does not preclude the use of measured components (Example – range and bearing). Computations based on use of such components should be clearly demarcated when presented (to differentiate from computations resulting in position information).

6.7.12 Testing of Protective Functions: The potential failure modes of position reference systems include failure to a condition in which they output erroneous position information. DPCSs are not immune to similar failures. Part of the validation and verification process is to confirm the effectiveness of these protective functions and the alarms that are used to warn the DPO that the PRS / DPCS has detected an anomaly and is taking action to remove it from the position solution.

6.7.13 Testing of protective functions is best carried out under controlled circumstances with the appropriate testing procedures and/or equipment. As these functions are generally implemented in software, within the DPCS, they can be tested by using simulator based testing. In this type of testing a test computer is used to simulate the position reference system and a comprehensive range of failure modes. The correct action of protective functions and alarms can be confirmed over a much wider range of conditions than is possible at sea trials or annual DP trials. Such a form of testing has been generically called Hardware in the Loop Testing (HIL).

6.7.14 Testing of internal protective functions with the PRS and verification any quality and integrity metrics typically carried out by the manufacturer.

6.7.15 Conventional methods employed during FMEA proving trials and annual DP trials may not be adequate to demonstrate the full functionality of protective functions.

6.7.16 Specialist support (Example – OEM resources) should be engaged in developing and undertaking testing.

6.7.17 Effective testing of relative PRS at DP FMEA proving trials and Annual DP requires the provision of suitable targets and transponders. Where such facilities are not available the first opportunity for testing may occur just prior to the DP operation to be undertaken. This precludes opportunities to remedy any faults or performance issues that may be detected as a less critical time.

7 CHOICE OF PRS AND MODES TO SUIT INDUSTRIAL MISSION

7.1 GENERAL

7.1.1 The guiding documents IMO MSC645 & 1580 provide the high-level statement referenced in Section 3.1.1 of this TECHOP.

7.1.2 It is acknowledged that DP equipment class does not specifically address operational requirements stated above. Thus, the specific modes required for the industrial mission and suitable PRSs are not covered by classification society rules.

7.1.3 It is thus incumbent upon owners and operators of vessels to ensure that their vessels are equipped with the appropriate PRSs and modes in the DPCS to conduct the industrial missions they intend to undertake.

7.1.4 Reliance on a DP equipment class notation alone to determine position reference requirements should be avoided.

7.1.5 PRSs should fail gracefully (failure should not result in a loss of position. Transfer if any should be bump less).

7.1.6 The systems approach should ensure that the design to test philosophy is embedded in PRS and DPCS (Software and hardware).

Note: It will be necessary to test software, (both functionality and protective functions). Conventional means of testing (Example - FMEA Proving Trials) on their own, will be inadequate for this purpose. Verification and validation activities should include appropriate and effective testing.

7.1.7 A summary of PRSs and categories of vessels (categorized by industrial mission) is given in Table 7-1.

Table 7-1 Categories of DP Vessels and Suitable PRSs

	Laser	Microwave Radius RadaScan	Relative GNSS (21)(22)	DARPS	Artemis	TW	USBL	USBL INS	LBL	LBL INS	GNSS	GNSS INS(20)
Logistics Vessels	Y(2)(3)(4)	Y(2)(3)(5)	N	N	N	N	N	N	N	N	Y(1)	N
Construction vessels(16)(17)(18)	Y(2)(3)(4)	Y(2)(3)(5)	Y(2)(3)(6)	N	Y	Y(15)	Y(13)(14)	Y(7)(14)	Y	Y(7)(10)	Y(1)	N
DP MODUs	Y(3)(4)(8)	Y(3(5))(8)	N	N	N	Y(15)	Y(13)(14)	Y(7)(14)	Y(9)	Y(7)(11)	Y(1)	Y(12)
DP Shuttle Tankers(19)	Y	Y	Y	Y	Y	N	N	N	N	N	Y(1)	N
Notes	1. Redundant GNSSs 2. When distance to surface facility is less than 150m may be used as position input – See Note H. 3. When distance to surface facility is greater than 150m may be used in monitoring mode only. 4. Prisms to be used – Minimum number of prisms 3 on each working side spatially and asymmetrically segregated. 5. Minimum number of transponders 2 on each working side spatially segregated. 6. Consider for specific industrial missions (Examples – Gangway connected operations off structures with movement). 7. Integration with INS enables PRS performance enhancement and addresses water depth (deep) restrictions. 8. MODUs should be outfitted with laser targets and microwave transponders to facilitate logistic vessel operations. 9. Dual independent with 2 arrays of a minimum of 5 transponders each. 10. LBL INS enhanced systems minimum of 4 transponders. 11. Dual independent LBL systems INS enhanced by 2 arrays of a minimum of 3 transponders each. 12. One GNSS with inertial INS aiding. 13. Water depth dependent USBL solutions in water depth less than 700m. 14. Minimum of 2 seabed deployed transponders. 15. Water depth dependent taut wire may be used in water depths less than 350m. 16. Industrial mission specific modes and features may be necessary (Example – External force compensation, follow target mode, pipe lay mode, heavy lift mode, etc.). 17. Gangway connected operations may use gangway as a PRS if instrumented. Gangway connected operations to take into account and address modes and features in PRS and DPCS. 18. Construction vessels engaged in industrial missions desirous of higher integrity and predictable station keeping have equipped themselves with inertial enhanced Acoustic PRSs and GNSSs (akin to configurations on DP MODUs). 19. DP shuttle tankers have sometimes been equipped with Acoustic PRS systems (conventional and inertially enhanced). This choice is usually driven by specific characteristics of the industrial mission. Example, offtake from submerged loading systems. 20. The use of inertially enhanced GNSSs is becoming more prevalent on all categories of vessels driven by their performance characteristics and affordability. 21. Does not use correction sources, depends on a radio link, increasingly prevalent on gangway connected DP accommodation units. 22. Relative GNSS use should address the issues of potential Interference / obstruction on radio communication link and location of antenna on attending facility (Temporary installations are more susceptible to issues).											

	Laser	Microwave Radius RadaScan	Relative GNSS (21)(22)	DARPS	Artemis	TW	USBL	USBL INS	LBL	LBL INS	GNSS	GNSS INS(20)
Additional Remarks	A. DP diving operations, by the nature of their criticality, should have a minimum of 3 PRS based on 3 different principles (not subject to the same common mode failures) B. This table summarises generic PRS recommendations. Nothing in this table precludes any type of vessel from fitting any type of PRS it deems necessary to meet IMO MSC645 & 1580 objective Section 3.4.3.1 'Position reference system' states: *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.* C. It is recognised that there may be specialist vessels that do not fit the four categories identified (Example – DP FPSO). D. Operational considerations may have an impact on the choices of PRSs. The benefits, risks and regrets should be evaluated against the consequence of a loss of position E. USBL depth limitations can be overcome with inertial aiding. The method of integration has an impact on maximum water depth. In water depths, greater than 1000m LBL solutions should be considered for specific industrial missions. F. Dual independent Acoustic PRS systems can use a single, shared seabed transponder array where each user's signals are segregated to remove interference risks. G. Optimisation of the number of seabed transponders (Example - shared arrays) may be considered for use with dual independent Acoustic PRS systems when the potential for interference risks are removed. H. Caution should be exercised when utilising a mix of absolute and relative position sensors for positioning when operating off non-earth-fixed facilities. Industrial mission specific requirements may dictate the need for additional modes and features in the DPCS. Clear and unambiguous instructions should be given in the vessel specific operations manuals. I. This table is not to be interpreted as a requirement for a particular type of vessel to have all the PRS listed. The listed PRS can be considered suitable for that vessel category within the limitations described by the notes above.											

7.2 PRS CONSIDERATIONS

7.2.1 The choice of PRS should be made with due consideration of the industrial mission being undertaken. The examples of factors to be considered are:

- Water depth (max and min).
- Proximity to surface assets and subsea architecture (identification of critical subsea architecture is essential).
- Positioning requirement (absolute or relative to a target), footprint limitations if applicable.
- Dynamic characteristics of the target if relative positioning is required.
- OEM recommendations for performance of systems to be strictly adhered to (Example - siting of targets, installation of equipment (including number of targets / transponders etc.) to be strictly adhered to.
- Limitations imposed by the industrial mission on choice of PRSs (Example – Deployment of Taut Wire precluded due to subsea architecture, deployment of transponders precluded due to lack of Ex ratings).
- The consequences of a loss of position.

7.2.2 Industrial mission specific modes and features may influence the choice of PRSs to be deployed. (Example – Follow target mode).

7.2.3 Non-essential interfaces to PRSs and DPCSs which could stimulate unpredictable behavior should be avoided (Examples – Speed latitude corrections into gyros that are used for DP, Tension inputs into DPCS, Doppler speed inputs into thruster control systems).

Note: A system’s engineering approach shall be applied where external interfaces are essential. Such a systems engineering approach should include an analysis of the failure modes. The analysis should cover both aggressive and benign failure modes. The analysis should be verified and validated by proving trials.

7.3 DPCS CONSIDERATIONS

7.3.1 The nature of the DPCS causes it to span redundant DP equipment groups. Such spanning of necessity requires comprehensive protective functions to prevent loss of position caused by erroneous or unpredictable behavior by PRSs.

7.3.2 Alignment of interface protocols and transparency of quality and integrity metrics between DPCS and PRSs is essential.

8 LEVERAGING DEVELOPMENTS IN TECHNOLOGY TO ENHANCE PRS AND DPCS HANDLING OF PRS.

8.1 NETWORKS

8.1.1 Use of networks for data communication in DP systems is common.

8.1.2 Principles of redundancy have been embraced in the network architecture to address failure modes.

8.1.3 Industry has reported incidents where the failures of both networks have been identified as casual and contributory factors.

8.1.4 Further, industry experience suggests that there are opportunities for improvement to be made in networks design and architecture. The objective of the pursuit of such opportunities should be to:

- Limit the amount of redundancy lost due to network issues.
- Ensure that loss of redundancy and performance is brought to the attention of the operator.
- Limit potential for hidden failures.
- Identify the need for protective functions.
- Eliminate capacity constraints.

8.1.5 Networks for vessel control systems have used solutions based on dual redundant industrial Ethernet for many years. With a few exceptions, connections to PRS and sensors have typically been made through individual EIA-422 serial links using telegrams defined in NMEA 0183. This standard is still widely used. The NMEA 0183 has evolved to NMEA 2000 but not applied to DP applications. The evolved NMEA standard is unlikely to address known issues associated with the use of NMEA 0183.

8.1.6 It is widely acknowledged in the DP community that continued use of this interface standard is likely to restrict innovation.

8.1.7 Typical issues encountered with the current PRS interface standard include:

- Lack of numerical precision in telegrams (not enough places after the decimal point).
- No field within certain telegrams to allow transmission of quality and integrity metrics.
- No field within certain telegrams to allow transmission of data for certain sensor types.
- Too many non-standard telegrams and interfaces are developed to overcome restrictions. This increases the opportunity for error and the burden of maintaining a large number of different interfaces.

8.1.8 Other industries such as the aerospace and petrochemical industry make extensive use of sensor technology and have similar requirements for high precision, reliability and fault tolerance in their control system and sensor network designs. Consideration should be given to exploring such established alternatives for sensor networks that provide the necessary performance, flexibility robustness, resilience, reliability and fault tolerance required by this and future generations of DP systems.

8.1.9 Alternate physical interfaces should be explored for PRSs. Propulsion systems have successfully used Ethernet based networks for such interfaces. The advantages and additional capabilities (Example - Data analytics, etc.) of adapting such interface technologies to PRSs could be an outcome. Such PRS and sensor networks should be independent of the DPCS control network.

8.2 OPEN STANDARD FOR INFORMATION EXCHANGE

8.2.1 Although it may be possible to identify a suitable networking standard, there may be merit in developing an open industry specific standard for the format used for communication between PRS and DPCS over a dual redundant 'Sensor' network. Development of an open standard for information interchange which is agnostic to the origins of the equipment being connected would remove current restrictions and provide the necessary transparency and promote innovation. Development and control of such a standard could be placed within the DP community.

8.3 MEANS TO ACQUIRE AND PROVIDE VELOCITY / ACCELERATION INPUTS

8.3.1 DP control systems use position feedback. The potential to improve the robustness of the DP control systems, particularly in poor weather conditions by use of acceleration and velocity measurements should be evaluated. Technological developments have addressed issues associated with the cost of the grade of sensors with the required attributes. The challenges of separating the required signals from other influences on the sensor have also been addressed. These factors which have been barriers should no longer limit their application.

8.3.2 It is acknowledged that the use of velocity and acceleration inputs for DP control purposes remains challenging, This, however, should not preclude the use of such measurements for monitoring and fault analysis and development of independent protective functions (Example – Alarms and dashboards in HMI).

8.4 INDEPENDENT PRS MONITOR AND PROTECTIVE FUNCTIONS

8.4.1 The development of sensor technologies based on inertial navigation principles has provided an opportunity to create an independent protective function that could operate alongside any DP control system to monitor the outputs from PRS and Sensors.

8.4.2 It is understood that several DP equipment vendors are currently considering what form such a system could take.

8.4.3 One potential arrangement would be for a system which monitors the position data transmitted to the DP system and provides independent confirmation that vessel movement detected by the PRS is genuine and not the product of some internal fault or other problem in the measurement process.

Note: The pros and cons of such a system independent of the PRS and DPCS should be evaluated against the pros and cons of providing such functionality within the DPCS.

8.4.4 This confirmation could be supplied to the DP control system along with other quality and integrity metrics and provide additional visual confirmation of sensor health to the DPO.

8.5 DASHBOARDS & HMI

8.5.1 Each PRS has a Human Machine Interface (HMI). This interface is usually in the form of an operator station with screen and keyboard which allows the operator to observe the preface of the PRS and change settings etc.

8.5.2 The severity of failure effects associated with failures in PRS are often reduced if the onset of a PRS failure can be identified and action taken to mitigate its effects.

8.5.3 Communicating information about the condition of the PRS could allow action to be taken to prevent undesirable consequences.

8.5.4 Dashboards are one method of providing information about a system in an intuitive, convenient and easily used form. A PRS dashboard could, for example, present quality and integrity metrics in the form of a traffic light system.
Note: Design of dashboards should consider principles of human factors engineering.

8.5.5 Due consideration should be given to represent the DP model as well in a similar fashion (i.e. traffic lights).

8.6 ALARM MANAGEMENT

8.6.1 Alarm management is the process of extracting more meaningful information from a series of low level equipment and machinery alarms. The intention is to reduce the cognitive burden on the operator and accelerate the diagnostic process.

8.6.2 An alarm management system can be deemed effective when it improves situational awareness while reducing:

- The time taken to identify extent and effects of equipment failures.
- The time taken by an operator to respond to prevent cascading or escalating failures.
- The cognitive burden on the operator.

8.6.3 Alarm management systems should facilitate operator intervention when appropriate.

8.6.4 Historically, alarm management systems applied to DP systems have not delivered their full potential to achieve the objectives stated in 8.6.2. One suggested strategy is to consider developing and alarm management system embedding systems thinking to address specific issues in the form of a decision support tool. Such an approach could lead to a natural extension of dashboards, standalone PRS/DPCS monitoring systems and protective functions as a means of reducing cognitive burden.

9 CURRENT REQUIREMENTS AND GUIDANCE

9.1 GENERAL

9.1.1 This TECHOP acknowledges the guidance available to industry which could be applied or adapted to achieve the objectives stated.

9.1.2 The references contained in this section are examples and not comprehensive.

9.1.3 It is anticipated that best practices contained within relevant guidance could be mined and adapted for use by the DP community.

9.2 IMO

9.2.1 Performance standards for GNSS and heading / track control system are published by the International Maritime Organization (IMO).

9.3 MTS

9.3.1 Information on the use of PRS is provided in the MTS DP Operations Guidance and in TECHOP_ODP_06_(D) (DGNSS POSITION REFERENCE SENSORS), September 2014. A TECHOP on acoustic position reference systems is in development at the time of writing this TECHOP.

9.3.2 It is expected that the existing TECHOPs and published guidance will be reviewed in conjunction with this TECHOP. Such a review may result in an updated revision.

9.4 CLASSIFICATION SOCIETIES

9.4.1 Classification society rules for DP and main class notations have general and specific requirements for PRS and related sensors.

9.5 OTHER INDUSTRY BODIES

9.5.1 Guidance on PRS and other subjects is available from the International Marine Contractors Association (IMCA).

10 SUGGESTED IMPLEMENTATION STRATEGY

10.1 GENERAL

10.1.1 It is acknowledged that the guidance provided in this TECHOP will need different strategies for application. It is anticipated that the strategies developed may be for the following categories:

- Existing vessels.
- New builds.
- Concept vessels being developed.

10.1.2 It is anticipated that implementation on existing vessels may take two-phased approach.

- Procedural barriers in the near term.
- Design barriers in the mid to long term.

10.1.3 Promulgation of the awareness of the issues and addressing of the same, both through a disciplined implementation of the guidance and potential innovation is expected to improve the delivery of predictable incident free DP operations.

10.2 NEW BUILDS AND VESSELS IN OPERATION

10.2.1 New builds should consider implementation of the guidance.

10.2.2 Currently available technology has enabled making conscious decisions in the choice of sensors based on operational requirements to deliver higher integrity solutions.

10.2.3 Planned and scheduled upgrades for vessels in operation should consider incorporation of this guidance when appropriate. Achieving predictability of outcomes should be one of the considerations in the evaluation process.

11 MISCELLANEOUS

Stakeholders	Impacted	Remarks
MTS DP Committee	✓	To track and incorporate in next rev of MTS DP Operations Guidance Document Part 2 Appendix 1. Communicate to DNV, USCG, Upload in MTS website part.
USCG	X	MTS to communicate- FR notice impacted when Rev is available.
DNV GL	✓	MTS to Communicate- DNV RP E 306 & 307 impacted.
ABS	✓	ABS Guide for Dynamic Positioning Systems
Equipment vendor community	✓	MTS to engage with suppliers.
Consultant community	✓	MTS members to cascade/ promulgate.
Training institutions	✓	MTS members to cascade/ promulgate.
Vessel Owners/Operators	✓	Establish effective means to disseminate information to Vessel Management and Vessel Operational Teams.
Vessel Management/Operational teams	✓	Establish effective means to disseminate information to Vessel Operational Teams.