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RELIABILITY SESSION

Use of the MTS Gap Analysis TECHOPS

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Introduction

There are many elements relating to design, operations and people that contribute to incident free DP operations. At the design phase of a DP vessel's life, the FMEA and the associated proving trials are key to establishing that the design of the DP system fully supports the redundancy concept.

During the operational phase, annual DP trials should confirm that the redundancy concept remains intact, that the DP system is performing as designed, that protective functions that are critical to supporting the redundancy concept are working as intended and that all alarms and other indicators that warn that the redundancy concept may be compromised are fully functional. The DP Operations Manual should provide key DP personnel with the necessary information to configure the DP system in the appropriate manner that supports the redundancy concept for each phase of the industrial mission, clearly detail the routine operational procedures for the DP operation and indicate the management of change necessary when the operational or technical situation changes, perhaps unexpectedly.

It is a fact that there is a wide variation in the quality and scope of the four documents mentioned above. There is a significant amount of guidance available on the relevant topics and the industry is starting to see a welcome convergence in guidelines emanating from the relevant industry bodies.

This paper and the accompanying presentation will cover the following:

- The importance of the documents in question (FMEA, Proving Trials, Annual Trials and DP Operations Manual) and the need for them to achieve the appropriate scope and quality.
- The availability of industry guidance on developing those documents.
- The development of the gap analysis tools based on the relevant industry guidance to enable an objective and consistent review.
- Practical use of the tools.
- Evaluating the outcome of the gap analysis (not a 'pass' or 'fail').
- The use of the gap analysis as part of a cycle of continuous improvement.
- Experience to date of using the tools.
- Future evolution of the tools

The Key Target Documents

DP System Failure Modes and Effect Analysis (FMEA) -

All dynamically positioned vessels of DP Equipment Classes 2 & 3 are required to be single fault tolerant in respect of defined failure criteria appropriate to the equipment class. Fault tolerance should be demonstrated to the satisfaction of the classification society. These requirements are traditionally satisfied by carrying out a Failure Modes and Effects Analysis (FMEA) which is validated by DP FMEA proving trials. FMEA is a rule requirement of all of the major classification societies offering a DP notation equivalent to IMO equipment classes 2 or 3.

Although the FMEA is a critical safety item on a vessel, there is wide variation in the quality and scope of FMEAs being approved as demonstrating fault tolerance. Failure to detect single point failures and vulnerability to common cause failures in the design of DP systems leaves the vessel vulnerable to loss of position and heading when the undetected failure mode occurs while carrying out DP operations.

The DP system FMEA must also take into account the industrial mission of the vessel and in particular address the interfaces between the DP system and industrial mission equipment which may include drilling systems, external force measuring systems, pipe-lay systems, dive systems etc. Industrial mission equipment may inadvertently provide fault propagation paths between redundancy groups and will almost certainly have its own power requirements which need to be reconciled with those of the DP system for station keeping.

DP System Failure Mode and Effect Analysis Proving Trials -

DP FMEA proving trials are intended to establish the level of redundancy and fault tolerance provided by the DP system and to confirm the analysis in the FMEA. The DP system (all systems required to maintain position and heading) of DP class 2 and DP class 3 vessels must be single fault tolerant in respect of defined failure criteria, which varies slightly from one classification society to another. A large number of tests and failure simulations are carried out at trials to prove that equipment and systems intended to provide redundancy have the necessary performance, protective functions and monitoring systems to ensure the integrity of the DP redundancy concept.

Testing is a vital part of any process intended to ensure the integrity of a fault tolerant system based on redundancy. There are three key elements in any fault tolerant system based on redundancies which are Performance, Protection and Detection. For a system to be considered fault tolerant in respect of its defined failure criteria, all DP related equipment must be capable of its nominal performance which includes dynamic attributes such as response time and accuracy not just steady state capacity. All protective functions designed to isolate faults and prevent them propagating from one redundant system to the other, must work effectively on demand. Protection may include automatic functions and procedural barriers, particularly in relation to internal and external common cause failures. Detection provides the means to identify when the system is no longer fully fault tolerant and that operations should be terminated. Detection may include alarms and monitoring but also periodic maintenance and testing such as annual trials.

DP Operations Manual -

The DP Operations Manual should provide the key DP personnel with the necessary information needed to configure the DP system in the appropriate manner that supports the redundancy concept for each phase of the industrial mission, clearly detail the routine operational procedures for the DP operation and indicate the management of change necessary when the operational or technical situation changes, perhaps unexpectedly. Therefore, the DP Operations Manual should contain relevant information on:

- Company policies and procedures.
- Vessel specific information with emphasis on:
 - The redundancy concept of the vessel.
 - The configuration that achieves the highest level of integrity of the power plant and station keeping critical equipment (Critical Activity Mode – CAM).
 - Alternate configurations (Task Appropriate Mode) that may be used.
 - The process that is in place to identify operations that must be operated in CAM and those operations that can be operated in TAM.
 - The processes that are in place to protect and defend the redundancy concept.
 - The necessary training and drills required to be carried by the personnel tasked with delivery of DP operations.
- Industrial mission specific information

Annual DP Trials Programme -

An annual DP trials programme should inter alia demonstrate that the DP system is fully functional, performing as intended with full power and thrust availability. It should verify the level of redundancy established by the FMEA and should verify the effectiveness of essential protective functions and alarms, i.e. demonstrate that the key elements of Performance, Protection and Detection are present in sufficient depth to give a high degree of confidence in the fault tolerance of the DP system.

Why Use Gap Analysis?

A gap analysis is a simple but useful tool for comparing any given document or process against a standardized checklist of requirements compiled from the applicable rules and guidelines. Use of such a standardized tool reduces the amount of subjectivity that may appear in an unstructured document 'review' based on one individual's own experience and interpretation of standards .

In the case of the DP system FMEA, IMCA M178 stated in 2005 that '*verification (of the FMEA) should be based on a comprehensive checklist (for example, a 'gap analysis') to confirm the items and areas that the FMEA has covered and to identify those areas that have been overlooked (refer to the list of DP components in IMCA M04/04).*

The ISM Code states that *'The Company should establish procedures for the preparation of plans and instructions, including checklists as appropriate, for key shipboard operations concerning the safety of the ship and the prevention of pollution'*. It also states that the company should ensure that *'Valid documents are available at all relevant locations'*. Clearly, any management system whether it is developed under the requirements of the ISM code, the USCG SEMS or any other regulatory regime requires effective document management including review and revision. Use of standardized gap analysis tools can play an important part in such document management.

Although DP vessel and MODU operators all have statutory safety responsibilities, in the oil and gas industry it is generally the field operators (oil companies) who assume the overall responsibility for safe operations within the field. The oil company will work in partnership with the vessel operators and others to develop safe operating procedures and practices. The oil company will be seeking a high level of confidence that the key documentation is fit for purpose in verifying the redundancy concept, providing a credible basis for development of ASOG/WSOG and assisting the crew in configuring the DP system to support and defend the redundancy concept throughout the entire operation. Use of the gap analysis tools will play an important part not only in the continuous cycle of improvement of the key documents but in giving both the vessel operator and the field operator confidence that their DP operational practices are developed on a sound footing when using the target documents as a basis for that development.

Development of the Gap Analysis Tools

The MTS guidance documents on DP covering 'Design' and 'Operations' were published by the MTS DP Technical Committee in 2011 and 2010.

The TECHOP system was subsequently established to promulgate valuable feedback received from stakeholders and additional guidance and information that the Guidance and Standards Sub-Committee wished to provide. Information contained within TECHOPS will be reviewed and incorporated into the principle documents upon their revision.

Recognizing the wide variation in the standard of the 4 critical documents discussed in this paper, over the last 2 years, the MTS Guidance and Standards Sub-Committee has published 4 standardised gap analysis tools either separately or as part of a wider ranging TECHOP. The purpose of developing and publishing these tools is to assist vessel and MODU operators in the continuous improvement of these safety critical documents:

TECHOP



**TECHNICAL AND OPERATIONAL GUIDANCE
(TECHOP)**

TECHOP_ODP_01_(D)_(FMEA TESTING)

OCTOBER 2013

TECHOP_ODP_01_(D)_(FMEA TESTING)_Ver2-10201308

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Figure 1 TECHOP ODP 01

TECHOP



**TECHNICAL AND OPERATIONAL GUIDANCE
(TECHOP)**

TECHOP_ODP_04_(D)_(FMEA GAP ANALYSIS)

DECEMBER 2013

TECHOP_ODP_04_(D)_(FMEA GAP ANALYSIS)_Ver5-12201312

1

Figure 2 TECHOP ODP 04

TECHOP



**TECHNICAL AND OPERATIONAL GUIDANCE
(TECHOP)**

**TECHOP_ODP_05_(O)
(DP OPERATIONS MANUAL)**

FEBRUARY 2014

TECHOP_ODP_05_(O)_DP OPERATIONS MANUAL_Ver2-02201413

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Figure 3 TECHOP ODP 05

TECHOP



**TECHNICAL AND OPERATIONAL GUIDANCE
(TECHOP)**

**TECHOP_ODP_08_(O)
(ANNUAL DP TRIALS AND GAP ANALYSIS)**

DECEMBER 2013

TECHOP_ODP_08_(O)_ANNUAL_DP TRIALS AND GAP ANALYSIS_Ver1-12201312

1

Figure 4 TECHOP ODP 08

The Use of Relevant Industry Guidance in the Development Process

Over many years, a plethora of rules and guidance has been written by various sources with an interest in dynamic positioning including the IMO, Flag States, Coastal States, Classification Societies and industry stakeholders such as IMCA, Nautical Institute and MTS.

Inevitably there have been contradictions between these various documents, aspects open to wide and varied interpretation or aspects not covered at all.

This variance is recognized by all industry stakeholders as unhelpful and there are clear moves towards harmonization. The MTS gap analysis tools are based upon the requirements contained within existing industry guidance. This gives a clear justification for the requirements and should remove subjectivity.

With regards to each individual gap analysis tool, the following rules and guidelines have been taken into account in the development of the tool in addition to the guidance contained within the TECHOP itself:

FMEA Gap Analysis:

Relevant classification society rules; DNV *Recommended Practice for FMEA of Redundant Systems- RP-D102*; IMCA Guidance M166 – ‘*Guidance on Failure Modes and Effects Analysis*’, April 2002; IMCA Information Note M04/04 - IMCA Study – ‘*Methods of Establishing the Safety and Reliability of DP Systems*’ – 2004, Appendices D & E in particular; MTS *DP Vessel Design Philosophy Guidelines Part II*; IMCA M206 ‘*A Guide to DP Electrical Power and Control Systems*’.

FMEA Proving Trials Gap Analysis:

MTS *DP Vessel Design Philosophy Guidelines Part II*; DNV *Recommended Practice for FMEA of Redundant Systems- RP-D102*; IMCA Guidance M166 – ‘*Guidance on Failure Modes and Effects Analysis*’, April 2002; IMCA Guidance M206 ‘*A Guide to DP Electrical Power and Control Systems*’ IMCA Guidance M190 – ‘*Developing and Conducting Annual DP Trials Programmes for DP Vessels*’, IMCA Guidance M191- ‘*Annual DP Trials for DP Mobile Offshore Drilling Units*’.

Annual DP Trials Gap Analysis:

Relevant classification society rules; IMCA Guidance M190 – ‘*Developing and Conducting Annual DP Trials Programmes for DP Vessels*’, IMCA Guidance M191- ‘*Annual DP Trials for DP Mobile Offshore Drilling Units*’.

DP Operations Manual Gap Analysis:

Relevant classification society rules; IMCA M103 ‘*Guidelines for the Design and Operation of Dynamically Positioned Vessels*’, December 2007; IMO MSC 695 ‘*Guidelines for Vessels with Dynamic Positioning Systems*’ –June 1994; IMCA M109 ‘*A Guide to DP-Related Documentation for DP Vessels*’ – February 2004, MTS *DP Operations Guidance Part II*

Practical Use of the Tools

Instructions regarding use of each gap analysis tool are included in the relevant TECHOP. Use is generally straightforward and should be intuitive to an experienced DP practitioner. Some features are deliberately common to all or some of the documents. It is generally assumed that a narrative report including a summary of the scope and conduct of the work together with the main findings would be attached to the completed checklists:

The FMEA Gap Analysis Tool:

The purpose of the gap analysis is to check the scope and methodology used in the DP FMEA against published industry guidance and not to repeat or correct the analysis. The gap analysis is typically carried out using only the FMEA report itself as source material.

The FMEA gap analysis can be performed using the table in Appendix A of the document. The large number of issues to be checked is indicative of the complexity of modern DP vessels and the number of systems, subsystems and equipment items that influence the redundancy concept. Checklist items related to the correct application of FMEA methodology are repeated in each subsystem which does create repetition but to restrict these issues to a single table entry is to risk overlooking essential elements of the analysis. The gap analysis table includes two types of issues to be checked: 1. Issues associated with application of DP FMEA methodology. 2. Lists of equipment and systems which would typically be discussed in a DP system FMEA.

TECHOP

A.2 REVIEW OF CONTENT

DP FMEA GAP ANALYSIS - FMEA DOCUMENT NUMBER AXXXXX-X										
DESCRIPTION				APPLICATION				GAP ANALYSIS		
SYSTEM	SUB SYSTEM	ITEMS FOR ANALYSIS	ID NO.	CLOSED BUSTIE OPERATION	OPEN BUSTIE OPERATION	DP CLASS 3	FAIL SAFE	CROSS REFERENCE TO FMEA	YES / PARTIAL / NO / NOT APPLICABLE GREEN / YELLOW / RED / GREY	CONCERN
Marine Auxiliary Systems	Fuel	Document reference with revision numbers.	1	✓	✓	✓				
		Location for DP Class 3.	2			✓				
		Description of fuel system and redundancy concept.	3	✓	✓	✓				
		System configuration for DP.	4	✓	✓	✓				
		Analysis identifies redundant groups in fuel system.	5	✓	✓	✓				
		Analysis identifies common points between redundant groups.	6	✓	✓	✓				
		Analysis identifies all failure effects that can propagate from one redundant group to the other.	7	✓	✓	✓				
		Analysis identifies any protective functions upon which redundancy depends to prevent failure effects propagating.	8	✓	✓	✓				

TECHOP_ODP_04_(D)_FMEA GAP ANALYSIS_Ver5-12201312

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Figure 5 FMEA Gap Analysis Checklist - Snapshot

A simple colour coding scheme (or narrative entry) can be used to identify whether the FMEA issues in the table have been satisfactorily addressed, partially addressed, omitted completely or contains significant errors. Grey can be used to indicate issues that do not apply to the design of the subject DP vessel.

- Green – Analysis satisfactory.
- Yellow – Analysis incomplete.
- Red - Analysis unsatisfactory (analysis omitted or contains significant errors).
- Grey – Not applicable.

Some items in the gap analysis list may only be relevant for DP equipment class 3 vessels or for vessels which operate with a common power system (closed bus tie). These items have a ‘tick’ mark in the relevant column, enabling the gap analyst to filter out irrelevant issues thereby reducing the volume of issues to be assessed (in some cases). A ‘tick’ in the ‘Fail Safe’ column indicates that the issue is related to systems which can fail in such a way as to cause a drive off, typically thruster control systems, DP control system, position references or sensors.

Where an issue is judged to be omitted or only partially covered then the concerns column should include some further comment explaining why the issue should be included or why it has been only partially covered. This comment is invaluable to the person tasked with review and revision of the target document.

Once all of the relevant issues have been assessed, then the ratio of reds / yellows / greens can be calculated to give an indication of the level of apparent compliance with the required scope and methodology.

The FMEA Proving Trial Gap Analysis Tool:

As with the FMEA gap analysis tool, the purpose is to check the scope and methodology used in the DP FMEA proving trials against published industry guidance and not to correct the trials programme. The gap analysis is typically carried out using only the FMEA and Proving Trials program as source material.

TECHOP

DP FMEA PROVING TRIALS GAP ANALYSIS - TRIALS DOCUMENT NUMBER XXXXX REVISION X – REVIEW OF CONTENT										
APPLICATION				GAP ANALYSIS						CONCERNS
SUB SYSTEM	TEST DESCRIPTION	CONTENT	ID NO.	CLOSED BUSTIE OPERATION	OPEN BUSTIE OPERATION	DP CLASS 3	FAIL SAFE	CROSS REFERENCE TO FMEA	YES / PARTIAL / NO / NOT APPLICABLE GREEN / YELLOW / RED / GREY	
DP Control System	Software Audit	Record software and firmware versions of all relevant DP equipment	1	✓	✓	✓				
DP Sensors	Gyrocompass XX	Failure modes for the Gyrocompasses	2	✓	✓	✓				
DP Control System	Heading Control and Heading Out of Limits Alarms	Check heading control and alarm limits	3	✓	✓	✓				
DP Sensors	Wind Sensor XX	Failure modes for all Wind Sensors (Record location data)	4	✓	✓	✓				
DP Sensors	MRU (Type XX)	Failure modes for all Motion Reference Units	5	✓	✓	✓				
DP Sensors	Draught Gauges	Failure modes for Draught gauges	6	✓	✓	✓				
Position References	DGPS Failures	Failure modes for the Differential Global Navigation Satellite Systems	7	✓	✓	✓				

Figure 6 FMEA Proving Trials Gap Analysis - Snapshot

The appearance of the gap analysis checklist is virtually identical to that for the FMEA although the number of issues is greatly reduced. The same process of filtering is used to further limit the number of issues to be addressed to those relevant to the equipment class and bus tie configuration. The process of completing the checklist and collating the results is identical to that previously used for the FMEA gap analysis.

The Annual DP Trials Gap Analysis Tool:

TECHOP 08 (Annual DP Trials and Gap Analysis) gives guidance on developing annual trials programmes for MODUs and other DP vessels using the related guidance contained within the IMCA documents M190 (for DP vessels other than MODUs) and M191 (for MODUs). The DP trials carried out on any DP unit need to demonstrate that the important elements of performance, protection and detection are present to support the redundancy concept. The gap analysis tool is structured to assist the analyst in establishing that this is the case. The tool can be used to analyse a programme developed in accordance with either M190 or M191 as the principles are the same.

It is important that the person tasked with carrying out the gap analysis is familiar with the DP redundancy concept. Ideally, the same person would have already carried out the gap analysis of the FMEA and proving trials. As a minimum, the FMEA must be available for review as part of the annual trials gap analysis process.

TECHOP

D.3 REVIEW OF CONTENT									
ANNUAL TRIALS GAP ANALYSIS - TRIALS DOCUMENT NUMBER AXXXXX-A									
DESCRIPTION			APPLICATION				GAP ANALYSIS		
TEST CATEGORY	TEST DESCRIPTION	ID NO.	CLOSED BUSTIE OPERATION	OPEN BUSTIE OPERATION	DP CLASS 3	PLANNED MAINT	CROSS REFERENCE TO TEST NO.	YES / PARTIAL / NO / NOT APPLICABLE GREEN / YELLOW / RED / GREY	CONCERNS
Performance	Does the Annual DP Trials program identify and test all those elements of the DP systems that may exhibit deteriorating performance?	1	✓	✓	✓				Redundant elements must be present in number and capacity.
	Generator 100% test	2	✓	✓	✓	✓			Vessel may lose position on failure of one redundant machinery group because the other has insufficient power.
	Thruster 100% tests	3	✓	✓	✓	✓			Vessel may lose position on failure of one redundant machinery group because the other has insufficient Thrust
	Network throughput test	4	✓	✓	✓				If both networks are not capable of carrying all the traffic the vessel will lose position if one network fails

Figure 7 Annual DP Trials Gap Analysis Checklist - Snapshot

The appearance of the checklist will now be familiar as it follows the same style as the FMEA and proving trials gap analyses. One slight modification is the addition of a column which indicates the type of test which may be adequately covered by a robust and well documented planned maintenance system if the developers of the annual trials programme choose to take advantage of that option espoused by the IMCA guidance.

Also, some further guidance has been given in the concerns column explaining the reasoning behind each of the tests and / or the consequences of failing to test where appropriate. It is expected that the gap analyst would replace these standard remarks with their own comments as the analysis progresses.

The DP Operations Manual Gap Analysis Tool:

Providing clear and unambiguous guidance to vessel teams on managing DP operations is essential to aid delivery of incident free DP operations. A comprehensive DP operations manual is a concise and effective way of providing such information.

There exists within the industry, several sources of guidance on the content of DP operations manuals. The MTS TECHOP dealing with DP Operations Manuals as well as the guidance contained within the MTS DP Operations Guidance draws together the available guidance but also identifies existing gaps particularly with regard to industrial mission aspects and configuration of the DP system for critical or non- critical activities, an area where many existing manuals are deficient.

TECHOP

7.3 GAP ANALYSIS CHECKLIST

DP OPERATIONS MANUAL GAP ANALYSIS - DOCUMENT NUMBER AXXXXX REV. Y DATED dd/mm/yyyy					
THE MANUAL SHOULD ADEQUATELY INCLUDE AND/OR COVER THE FOLLOWING ISSUES AS APPROPRIATE	ID NO.	SOURCE OF REQUIREMENT	CROSS REFERENCE TO DP OPERATIONS MANUAL	SUBJECT COVERED? YES / PARTIAL / NO / NOT APPLICABLE GREEN / YELLOW / RED / GREY	COMMENT / CONCERN
Management of DP Operations:					
Company policies. DP should be identified as a safety critical element.	1	MTS Ops Guidance Part 2 IMCA M109 Sec 3.2.4 IMCA M109 Sec 3.2.7 TECHOP ODP 05 Sec 4.1.2 TECHOP ODP 05 Sec 5.1.1			
Basic principles of DP including a functional overview of a DP system.	2	MTS Ops Guidance Part 2			
Vessel specific overview of the DP system and industrial mission equipment including different control modes (e.g. heavy lift, follow sub, pipelay, thruster bias, quick current etc.)	3	MTS Ops Guidance Part 2 IMCA M109 Sec 3.2.3 IMCA M109 Sec 1.5 TECHOP ODP 05 Sec 5.2.1 TECHOP ODP 05 Sec 5.5.3 ABS Guide to DP Systems- Sec 2 Ch 13			
Vessel specific DP philosophy to include reference to CAM / TAM; ASOG; system configuration (e.g. open / closed bus); worst case failure design intent (WCDFI) and worst case failure (WCF); environmental limits; station keeping capability. Vulnerabilities of the DP system should be discussed and configurations that may defeat the redundancy concept described.	4	MTS Ops Guidance Part 2 IMCA M109 Sec 3.2.5 IMCA M109 Sec 3.2.8 TECHOP ODP 05 Sec 4.1.2 TECHOP ODP 05 Sec 5.2.1 TECHOP ODP 05 Sec 5.5.1 ABS Guide to DP Systems- Sec 2 Ch 13			
Vessel specific philosophy for converting drive off to drift off.	5	MTS Ops Guidance Part 2 IMCA M109 Sec 3.2.8			
References to other relevant DP guidance and reference documents including but not limited to: DP system FMEA; equipment manuals; MTS guidance; IMCA guidance; technical and safety bulletins; Class Society rules, client specific requirements.	6	MTS Ops Guidance Part 2 IMCA M109 Sec 3.2.4 IMCA M109 Sec 3.2.7 IMCA M109 Sec 3.2.11 TECHOP ODP 05 Sec 5.3.1 ABS Guide to DP Systems- Sec 2 Ch 13			

TECHOP_ODP_05_(O)_DP OPERATIONS MANUAL_Ver2-02201413

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Figure 8 DP Operations Manual Gap Analysis Checklist - Snapshot

The checklist contains approximately 100 issues to be considered split into 4 subsections which align with the manual structure suggested in the MTS Operations Guidance i.e. '*Management of DP Operations*'; '*DP System Description and Operation*'; '*DP Operations Procedures*' and '*Organisation and Responsibility*'.

The layout is broadly similar to the preceding gap analysis tools with the addition of a column which states the source of the requirement for a particular issue to be included in a DP Operations Manual. This column is intended to be a source of reference to both the person conducting the gap analysis and those subsequently tasked with reviewing and revising the document. Reference to the industry guidance will give more detail and context to the relevant issue being considered.

When to Carry Out the Gap Analysis:

The gap analysis tools can be used to evaluate the relevant documents at any stage in that documents lifecycle. As well as carrying out a gap analysis as part of the ongoing cycle of review and revision, the tools can usefully be used during the document's initial development. This is particularly important in the case of the FMEA. A good quality FMEA is essential if design deficiencies which may undermine the vessel's redundancy concept are to be detected at an early stage. This gives the opportunity to remedy such deficiencies before the cost becomes prohibitive. A gap analysis should give confidence that the scope and methodology of the FMEA gives the best chance to detect such design deficiencies.

Evaluating the Outcome

It is important to understand that the gap analyses are essentially a method of evaluating the methodology and / or the scope of the documents in question. The gap analyses are not intended to be a means by which the design of the DP system of the vessel is reviewed or the conduct of shipboard activities is assessed. These tasks are better covered by different tools and methods.

In the case of the FMEA gap analysis it may be that the outcome indicates that the FMEA is based on sound methodology, has identified all of the relevant systems and analyzed all of the possible failure modes of those systems and has revealed many serious deficiencies in the design which can defeat the redundancy concept and therefore the fault tolerance of the vessel. Therefore, it is the DP system design which is deficient, NOT the FMEA. In the same way, gap analysis of the FMEA proving trials or the annual DP trials is looking to verify that the trials programme has been developed correctly from the FMEA, that it identifies all of the elements of performance, protection and detection that must be tested, either to validate the desktop FMEA analysis or to demonstrate on an annual basis that the redundancy concept remains intact. The gap analysis practitioner should avoid being distracted by the actual results of the tests if analyzing a completed test programme. It is important to understand that a good outcome from the tests if analyzing a completed test programme. It is important to understand that a good outcome from the gap analysis does not necessarily indicate a sound DP system design, adequate testing or confirm that sound operating practices are being conducted. A good gap analysis outcome simply confirms that the documents in question have been developed properly and sufficiently and will provide the best chance for achieving a good design (or remedying a poor one), carrying out appropriate testing and putting good operational practices into force.

It is important to understand that although the gap analyses produce a 'score' (i.e. the ratio of items covered / items needing further analysis or explanation / items not covered at all), there is no pass or fail mark. It would be unhelpful to attempt to identify the ratio which indicates a 'satisfactory' document. Clearly, documents which are assigned a high proportion of 'reds' should be given high priority for review and revision but the purpose of the gap analysis tools is to provide a starting point, a reference for those with the responsibility for continuous document review.

A low 'score' does not necessarily indicate that the document is not fit for purpose. It may be the case that some missing information regarding the redundancy concept, the critical activity operating configuration or details of the industrial mission leads to a cascade effect of items in any of the gap analysis tools being marked as 'red' because their relevance or otherwise is unclear to the person conducting the gap analysis.

One way in which contemporary FMEAs can appear deficient when measured by the gap analysis tool is due to a lack of transparency in the analysis. That is to say, it is not possible to verify from the FMEA alone whether an important item of analysis has been overlooked, or is not required, because the FMEA is silent on the subject. The gap analysis tool has a mechanism to discount analysis of systems where it is obvious from the design or type of the vessel that such systems are not present but in other cases, the gap analysis will indicate a deficiency and the FMEA may score poorly because of this.

This principle of transparency is also relevant to the other three documents covered by the gap analysis tools. If the redundancy concept and industrial mission is clearly explained, then it should be apparent to the analyst which tests are applicable or not as the case may be, which operational procedures should be contained within the Operations Manual and which DP system configurations need to be considered by all of the documents. This will lead to a more concise report and therefore ease the task of those using the outcome of the gap analysis to review and revise the document in question.

Experience to Date

Several stakeholders have conducted gap analyses and decided to completely renew their FMEAs, annual DP trials programmes or DP Operations Manuals where the analysis has revealed numerous or serious deficiencies. Usually this is because the documents are old and have not been subject to a suitable process of continuous review and revision.

Stakeholders using the gap analysis tools to date have included oil companies, MODU operators and also construction and logistics vessel operators.

Limited experience has been gained to date in using the outcome to revise rather than replace the target document, but it is expected that this will change as stakeholders adopt the gap analysis tools as a means to facilitate review and revision of the documents as part of the continuous improvement cycle.

DNVGL (Noble Denton Marine Assurance and Advisory) have carried out a significant number of gap analyses on the documents covered by the MTS tools. It is fair to say that the older a document is, be it FMEA, trials or DP Operations Manual, then the lower it has been found to score. Documents produced in the last 2-3 years tend to score higher (although there are of course exceptions). This is undoubtedly mainly due to the improvement and convergence of guidance from the industry stakeholders including the class societies, MTS, IMCA and other bodies.

Experience to date using the gap analyses has raised the following main areas of concern:

- For FMEAs – a lack of clarity regarding configuration of the power systems. Failure to consider failure effects other than benign. Failure to focus on external interfaces (particularly with industrial mission equipment) and cross connections between redundancy groups. Failure to analyse protective functions and confirm plant stability and voltage dip ride through for closed bus operations in sufficient depth.
- For proving trials and annual trials, as expected, the gaps are very similar to those identified in the FMEA i.e. clarity of configuration, benign rather than aggressive failure effects and a lack of rigorous testing of protective functions.
- DP Operations Manuals often lack the information needed to configure the DP system to support the redundancy concept with very little mention of the concepts of CAM or TAM. There is often a lack of mission specific guidance. It could be theorized that the generic nature of many DP Operations manuals is because they are often prepared by 3rd parties working from limited information (perhaps only the FMEA) and without sufficient involvement of the vessel's operational team.

Future Improvements

The gap analysis tools have been developed in a relatively short space of time and it is natural that based on experience gained, review and revision of those tools will be necessary to improve their scope, methodology and usability.

It is anticipated that the FMEA gap analysis tool is a priority for any revision. By necessity it is a large document and some feedback indicates that some of the checklist items need some expansion in the way of further guidance to assist the user in understanding the intent of the question. However, it is expected that users should have sufficient experience to understand the issues raised by the gap analysis checklist.

Further guidance could be added to the template documents in the style of the current annual DP trials tool.

Spreadsheet versions with filters to assist in tailoring the documents for equipment class and configuration are under development.

Conclusion

The MTS gap analysis tools have been developed with the intent of assisting vessel or MODU operators to continuously review, verify and develop some of the key DP documents that play a safety critical role in their DP operations. The gap analyses are based on the relevant industry rules and guidelines and therefore should prove to be suitably objective.

Use of the gap analyses will provide vessel operators with a benchmark of the key documents and this will guide the efforts of those charged with revising the documents

Because these gap analysis tools are intended to raise standards across the industry they set a high, but entirely achievable, standard.