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VERIFICATION, TESTING AND TRIALS

FMEA – Fail to Meet Expectations Again?

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Introduction

A Failure Modes and Effects Analysis (FMEA) is required by class for any Dynamically Positioned (DP) vessel for Class 2 or Class 3. There are however justifiable concerns over the adequacy of this technique and the quality of many FMEAs that are produced for DP vessels. For instance - why are some many single point failures still found after and FMEA has been performed? This paper will examine the problems of FMEA applied to Dynamic Positioning plus the standards and requirements for FMEA, that are or could be used to ensure a more adequate FMEA is obtained. The problems and limitations of FMEA are discussed and industry standards reviewed. The qualifications and competence required of the FMEA team will be discussed and guidelines given. As will the level of detail required of the analysis and the testing.

In short the paper should assist any shipyard, vessel owner or oil company in understanding FMEA, specifying an FMEA and assessing its adequacy and correct level of detail. The process of FMEA is not perfect, this paper seeks to show how it can be made better. The paper is an extension of a part paper presented at the MTS DP conference in 1997 in conjunction with Howard Shatto.

Background

Owners, operators and charters of Dynamically Positioned (DP) vessels seek to have redundancy built into the system when the consequences of a failure are such that there may be a danger to life, and or there may be serious economic consequences, such as damage to equipment or vessel down time.

As Dynamic Positioning was used more for vessels performing saturation diving the desirability of fully redundant systems for this application also became apparent after some serious accidents or near accidents on DP vessels. These resulted in the UK and Norwegian authorities producing joint guidelines for DP diving vessels and then later DP drilling vessels. These addressed the DP control system but also its supporting systems, as well as the operational procedures the vessel personnel should follow and their training. Class initially by DNV then followed by Lloyds, ABS and others also took up these matters. The class rules generally only deal with equipment and do not deal with operator competence, training etc. To fill this gap and to help self regulate their industry the DP Vessel Owners Association (DPVOA) was setup and produce Guidelines for the Design and Operation of DP Vessels as well as guidance on the training of DP operators and associated personnel. These DPVOA documents (now issued under IMCA) have been adopted almost totally as part of IMO guidelines for DP.

Objectives of a DP FMEA

The objective of an FMEA, as applied to a DP vessel, should be to provide a comprehensive, systematic and documented analysis to establish the important failure modes with regard to station keeping. The analysis must seek to determine any failure modes that can affect the station keeping as a whole and cause a position loss. The possible modes of position loss are:

- Drive off
- Drift off
- Large excursion

The analysis seeks to find any single point failure in any of the total DP system that can cause any of the position losses stated. The FMEA of a DP vessel is based on a single failure concept under which each system's subsystems and parts are assumed to fail by one probable cause at a time. It must in effect make sure that the stated worse case failure for the vessel cannot be exceeded by any single failure.

It is also customary to include a single act of mal operation as a possible single failure. This is assessed when a mistake is easy to make due to system layout where a single act has severe consequences. 'Single act' is a subjective definition and is generally taken to mean the operation of a single button, lever or switch.

The analysis must also consider hidden failures; this is a failure of a back up or standby without an alarm so that a second failure is not realized until the initiating single failure has occurred. For instance a standby pump being faulty; or a UPS having a faulty battery and being unable to take load when required. It must also consider that on some vessels that are in continuous operation, such as drilling vessels, will have some equipment may be down for maintenance for long periods of time.

Any failure mode, which may cause a catastrophic loss of position, should be shown by the analysis to be guarded against by system or equipment redundancy, unless the probability of such a failure is extremely low. For some failure modes it may be reasonable to accept corrective measures in lieu of redundancy. It may also be acceptable to have procedures in place that mitigate or reduce the probability of a potential failure going undetected. For example a DP watch keepers check list can be used to check; for example that all the acoustic systems are not on the same vertical reference unit; mobilization or field arrival trials can be used to check all back up pumps, back up battery supplies etc.

In addition the analysis must search out common cause type failures. These are more difficult to find as they are often the result of a secondary effect of a first failure and effect. For instance loss of one half off a switchboard due to a short circuit results in the thrust doubling on the other. Along with transients in voltage and frequency caused by the short and its clearance may cause the other board may also trip.

Scope of a DP FMEA

Originally, and to some extent even now, the term 'DP system' tended to mean just the DP control system, however the term is now used for the entire vessel's systems that are needed to support and keep it on position. These include the power generation, power distribution, thrusters, and even the operators, as well as the DP control system itself. Systems to be covered should typically include:

Power Generation	prime movers, generators, fuel system, seawater cooling, fresh water cooling, lubrication, compressed air, ventilation.
Power Distribution	high voltage, medium voltage, low voltage ac, low voltage dc, control supplies,
Thrusters and Propulsion	drives, control system, cooling, lubrication, hydraulics, manual to DP changeover, DP interface
Power Management	load sharing, load shedding, load reduction, and black out recovery, DP interface

DP Control System	input output system, data highways, position reference system processing, DP changeover, DP power distribution, UPSs, power limiting, control modes, operator interface
DP Sensors	gyros, vertical reference sensors, wind sensors
DP Position Sensors	acoustics, taut wire, DGPS, riser angle etc
Human Factors	capability plots, footprints, communications systems, operator competence, operator (DP and ECR) training, operator experience, working conditions, check lists, operations manuals, standing orders, man machinery interface

Level and Format of a FMEA

Most FMEAs of DP vessels are based on the functional and hardware partitioning of the system into descriptive and block diagram form. The level at which this partitioning takes place, i.e. to what component level, plus the form of the analysis determines the detail to which the analysis will be performed. The more detailed a study the lower the risk of missing a critical failure but the higher the cost. However the cost of the FMEA may be repaid many times over if it prevents an expensive incident.

Often though it is not necessary to proceed into the detailed FMEA of a particular item if it can be decided at the higher level that it is not critical and need not be investigated further.

The format also affects the cost and level of analysis. One approach is to provide a description, and possibly a block diagram, of each vessel system that is essential to the positioning of the vessel, its method of operation and possible failure modes. This provides the rationale by which the failure effects can be established.

The format can be made more detailed by performing the analysis using a tabulated format. This forces the analysis into a more systematic approach and requires each part of the table to be considered. The more comprehensive the table's format the more detailed the analysis will be. A typical simple set of table headings might be:

FAULT	SYSTEM EFFECT	BACK UP	SYSTEM/ALARM

A more detailed format might be:

ITEM NOS	COMPONENT	FUNCTION	FAULT	FAULT DETECTION	RESULTING ACTION	OPERATOR INFORMED BY	REMARKS

The tabulated format can just as well be presented in a fault tree type presentation where the sequence of events following a failure from top to bottom of the 'tree'.

The tabulated format is the more analytical but can restrict the freer thinking that may be necessary to find some of the single failures. The descriptive analysis is better for this, so generally a mixed approach is best. In addition the descriptive part should demonstrate the analyst's full understanding of the DP system he is analyzing. The fault tree is the most easily read but may be too time consuming to do for every conceivable fault, it can however still be used in combination with the other techniques for specific very critical failures.

Other concepts that may want to be introduced are: criticality (or severity) and probability with this an attempt is made to grade the severity and probability of all the failures. The probability can be a simple classification into low (extremely improbable), medium (remote possibility) and high (frequent and reasonably possible). The severity can also be into categories based on consequences e.g. catastrophic, hazardous, major, and minor. These may be a subjective categorization based on experience or be based on reliability figures from historical data or specific studies. A catastrophic consequence as a result of a extremely improbable failure may be accepted as reasonable. Similar minor consequences of a reasonably possible event may be acceptable. Other combinations will not.

Problems with FMEAs of DP Systems

Timing

To obtain maximum benefit from a FMEA is important that it is performed at the appropriate time in the design process of a DP system. This is however difficult to time because the design needs to be far enough along to have something to analyze. It must not though be so far along that it cannot be altered based on the findings of the FMEA. A FMEA can still be of great benefit even if it is performed on an existing system as it can reveal limitations and some solutions need not be major but still be worthwhile. The optimum is to perform the FMEA at the design stage and continue enhancing it through the duration of the whole project, finally updating it after sea trials, and then retesting and revising it following future modifications to the system.

Too often a fast track project or one that goes late results in production pressures on the FMEA and its testing.

Design

Designers of DP systems often see an FMEA as a criticism of their design. However all designers of safety critical systems should and do design with failure in mind. The FMEA is simply a double check on this process. If the design is done with the FMEA in mind to begin with then the findings of the FMEA are going to be less influential on the design itself.

Software

It is difficult to FMEA the DP control system software as its failure modes should generally result in a watchdog trip or a total system crash. To check it for other failure modes all possible failure modes of its inputs need to be considered and the software's reaction to them can be used to realize the failure effects.

Similarly any failure in the software would be similar to the possible failure modes of the DP control system's outputs.

As far as the author is aware no one has a systematic away to FMEA software, although some attempts have been made. Generally checking of the software can only be achieved by analyzing the possible failures of the inputs and outputs of the system. The software engineers that understand how the software should react to the failure modes should check the analysis. Testing must also be used to check them.

Failures

Fundamental to the success and usefulness of the FMEA is the expertise and experience of the person or persons performing the analysis. A DP system encompasses many different engineering disciplines it may therefore require a multi discipline team to perform the FMEA. Experience of DP is also needed. Wide personal experience has to be drawn upon but another useful source of experience is the IMCA database of DP incidents. This is a collection of real DP incidents reported to IMCA, these have been collected over many years. These provide event trees of incidents that resulted in a position loss to the surprise of the operator. It is interesting to note that at least half of all such incidents are attributed to operator error, not just the DP operator but any person associated with the positioning of the vessel.

Confirmation

Initially the FMEA is a paperwork theoretical analysis. However to be assured that the theoretical analysis is correct; proving trials have to be conducted on the vessel to verify the findings of the FMEA. The FMEA of the DP control system in particular should be used as a basis for the factory test procedures it is to meet. This can impact the cost and program for the DP system and the vessel itself, however the costs saved later when a fault may occur for real and expensive damage is done.

DP Control System and Power Management

The detailed FMEA of these items is invariably provided by the DP control system. Care must however be exercised with this as they tend to be rather incestuous and self proving. It is however difficult to get these checked. At a minimum and engineer not involved with the particular project should conduct the analysis.

Dual Networks

Dual networks are now the vogue and very difficult to analyze and even to meaningfully test. Result might vary depending on network loading at the time of failure. Often the networks are proprietary systems that are not designed by the DP control system suppliers.

Expectations

FMEA is not perfect it is a tool that will find many of the problems, but not all.

Class Rules for FMEA

The main Class Societies all have rules on the design on DP systems. DNV were the leader in this field in the 1970s. ABS and Lloyds also now have DP rules. IMCA has Guidelines for the Design and Operation of DP vessel, and IMO have requirements. This section of the paper will review these from what they expect from an FMEA.

***Det Norske Veritas DNV** ('old rules' January 1990)* **-**

The rules have recently been revised (see below) – the existing rules have this to say about the FMEA of a DP system.

E 600

*601 Documentation of reliability and availability of the DP system **may** be required in the form of a Failure Modes and Effects Anaylsis (FMEA)*

602 The purpose of the FMEA is to give a description of the different failure modes of the equipment referred to its functional task. Special attention is to be paid to analysis of systems where an item may enter a number of failure modes and thus induce a number of different effects on the DP system performance. The FMEA is to include at least the information specified in E603-E605.

603 A functional breakdown of the DP system, or subsystem into functional blocks is to be made. The functions of each block is to be described. The breakdown is to be performed to such a level of detail that the functional interfaces between the sub-functions within the respective functions are shown.

604 A description of each physically and functionally independent item and the associated failure modes with their failure causes related to normal operating modes of the items is to be furnished.

605 A description of the effects of each failure mode alone on the system and the overall DP system is to be made.

It is also interesting to note the following rule that allows for no FMEA at all provided testing is performed. However how the test procedure is to be decided without an FMEA is not explained. Several vessels to the author's knowledge have got through class by using this rule.

D 400 Verification of redundancy and independence

D401 Redundancy and independence are to be verified either by:

- a Failure Modes and Effect Analysis (FMEA)

or

- test program, covering all relevant failure modes to be carried out during trials.

And

701 As an alternate to an FMEA, the redundancy may be documented in a test procedure covering all the relevant failure modes, and which is subsequently verified during sea trials.

There are new rules in the process of finalization by DNV. These may be in force by the time this paper is published. These state the following.

***Det Norske Veritas DNV** ('latest rules' January 2001*

DNV have recently reissued their rules for DP and the key parts of them that relate to FMEA are given below.

Failure: *An occurrence in a component or system causing one or both of the following effects:*

-Loss of component or system function

-Deterioration of functional capability to such an extent that the safety of the vessel, personnel or environment is significantly reduced.

Guidance note:
For vessels that are to comply with ***AUTRO*** *requirements, the definition of single failure has no exceptions, and shall include incidents of fire and flooding, and all technical break-downs of systems and components including all electrical and mechanical parts*

For vessels that are to comply with ***AUTR*** *requirements, certain exceptions will be allowed in the definition of single failure. Flooding and fire are not to be considered beyond main class requirements. Failure of non-moving components, e.g. pipes, manual valves, cables, etc. may not need to be considered if adequate reliability of a sing component cant be documented, and the part is protected from mechanical damage.*

D600 Failure mode and effect analysis (FMEA)

601 *For vessels with the notations* ***AUTR*** *and* ***AUTRO,*** *documentation of the reliability of the dynamic positioning system is required in the form of a failure mode and effect analysis (FMEA)*

602 *The purpose of the FMEA is to give a description of the different failure modes of the equipment when referred to its functional task. Special attention is to be paid tot he analysis of systems that may enter a number of failure modes and thus induce a number of different effects on the dynamic positioning system performance. The FMEA is to include at least the information specified in 603 to 605.*

603 *A breakdown of the dynamic positioning system, into functional blocks is to be made. The functions of each block are to be described. The breakdown is to be performed to such a level of detail that the functional interfaces between the functional blocks are shown.*

604 *A description of each physically and functionally independent item and the associated failure modes with their failure causes related to normal operational modes of the item is to be furnished.*

605 *A description of the effects of each failure mode alone on other items within the system and on the overall dynamic positioning system is to be made.*

Guidance note:
Description of FMEA systematic may be found in IEC Publication 60812 and IMO HSC Code, Annex 5

E 700 ***Redundancy tests for AUTR and AUTRO***

701 *A selection of tests within each system analyzed in the FMEA for the different systems are to verified by tests when redundancy or independence is required.*

702 *The test procedure for redundancy is to be based on the simulation of failures and shall be performed under as realistic conditions as practicable.*

Section 2 - B 300 ***Failure modes***

301 *For class notation **AUTR** the loss of position is not to occur in the event of a single failure in any active component or system. Normally static components will not be considered to fail if adequate protection is provided. Single failure criteria for **AUTR** include:*

-any active component or system
-static components which are not properly documented with respect to protection
- a single inadvertent act of operation. If such an act is reasonably probable
-systematic failures or faults that can be hidden until a new fault appears

Note now that they now require an FMEA and proving trials and that the reference IEC which is discussed later in the paper. They also state that a 'single inadvertent act of operation' and systematic/hidden failures must also be considered.

American Bureau of Shipping - ABS

ABS 2000 DP Rules state the following requirements for an FMEA.

A failure mode and effects analysis (FMEA) is to be carried out on the entire DP system. The FMEA to be sufficiently detailed to all the major systems' major components and is to include but not be limited to the following information.

- *A description of all the systems' major subcomponents and a functional block diagram showing their interaction with each other.*
- *All significant failure modes.*
- *The most predicable cause associated with each failure mode*
- *The transient effect associated with each failure mode*
- *The method of detecting that a failure has occurred*
- *The effect of the failure upon the rest of the system's ability to maintain station*
- *An analysis of possible common failure mode*

ABS is the only class society to identify that there may be some non redundancy identified by the FMEA.

Where parts of the system are identified as non-redundant and where redundancy is not possible, these parts are to be further studied with consideration given to their reliability and mechanical protection. The results of this further study are to be submitted for review.

Along with DNV ABS require trials that are be based on the FMEA.

Upon completion of the installation of the dynamic positioning system, complete performance trials are to be carried out to the surveyor's satisfaction at the sea trials. The schedule of these tests is to demonstrate the redundancy established in the FMEA.

It is also worth noting that ABS has requirements for FMEA for computer systems and vessel that are ACU or ACCU (unmanned machinery space).

4/11.3.7Computer Based Systems

c Failure Modes and Effects Analysis (FMEA) (1996) In case of computer based systems for which the safety functions are not backed-up by hard - wired safety systems, an FMEA is to be performed and submitted for review.

4/11.7.2 Equipment and System Integrity (1996)

b Failure Modes and Effect Analysis (FMEA) The integrity of the associated automatic or remote control and monitoring system is to be verified by means of a failure modes and effects analysis (FMEA) or equivalent method on the basis of a single mode failure criteria. The analysis is to show that no single failure will lead to such a condition that endangers human safety and/or the vessel. A failure mode and effects analysis (FMEA) is to be submitted for review.

Lloyds Register of Shipping

For vessel requiring assignment notation to AA and AAA – class 2 and class 3 respectively. Lloyds rules have the following requirements for an FMEA.

For assignment of DP(AA) and DP(AAA) notation a failure modes and effects analysis (FMEA) is to be submitted verifying that the requirements of section 4 and section 5, as applicable, have been met.

As far as trials are concerned the rules read as follows

The suitability of the dynamic positioning system is to be demonstrated during sea trials, observing the following:

> *(a) Response of the system to simulated failures of major items of control and mechanical equipment, including loss of electrical power.*

Bureau Veritias – BV

Have probably the simplest requirements of all.

- failure modes effect analysis using as far as possible the fault tree method.

For trials-

Tests are to be performed in order to assess the appropriate response to

- simulated extreme environmental conditions,
- failures (controller, position reference system, gyrocompass, alternator, thruster).

International Guidelines

International Marine Contractors – IMCA

IMCA Guidelines for the Design and Operation of DP Vessels have the following requirements.

For all dynamically positioned vessels, all failure modes and their effects should be considered in a formal FMEA study. The modes that should be considered are; firstly, the sudden loss of major items of equipment; secondly, the sudden or sequential loss of several items of equipment with a common link; and thirdly, various control instability failures and their method of detection and isolation. Faults that can be hidden until another fault occurs should also be considered. For each fault the likely operator responses, based on the information available to him, should be assessed. Operator responses to the three types of failure mode mentioned above should be reflected in the operations manual for operational scenarios for which the vessel is intended.

These failures and their effects should be assessed in the light of the basic design philosophy outlined in 1.1, and the relevant subsequent section for the type of vessel and operation. The FMEA should also consider likely operational scenarios of the vessel such as shallow water, high tidal streams and working close to fixed installations as applicable. The FMEA should be updated if modifications are made that are likely to effect the FMEA's conclusions

Extent of Dynamic Positioning FMEA Proving Trials

Dynamically positioned vessels have to undergo FMEA proving trials, in addition to and after, dockside testing, commissioning and customer acceptance trials.

> *The dynamic positioning system should be proven as far as is reasonably practicable in all the normal modes of operation that will be likely during the life of the vessel.*

When all normal modes of operation appear to be functioning correctly, failure modes should be simulated and the results of such tests independently documented by a third party. Finally, performances should be demonstrated in both the intact and various failed conditions. (Moderate or rough weather is ideally required for these tests, but is not essential for acceptance of the DP capability and system stability).

The guidelines also have something to say about trials.

Such proving trials should be properly documented and the results available to operators, owners, charterers, surveyors and responsible authorities, to obviate the necessity of repetition of some of the design related trials during the vessel's working life and as input into operational manuals and vessel familiarization as appropriate.

International Maritime Organisation IMO

Although there is no reference to and FMEA in IMO's – Guidelines for Vessel with Dynamic Postioning - they do have something to say about failures. They do address operator error as follows

For equipment classes 2 and 3, a single inadvertent act should be considered as a single fault if such an act is reasonably possible.

The class societies have more to do with equipment rather than operation. However IMCA are more interested in operation and IMO go as far as to state:-

For equipment classes 2 and 3, a single act should be considered as a single fault if such an act is reasonably probable.

Also in IMO they have an interesting rider on Class 3 that is also echoed in ABS.

3.1.3 For equipment class 3, full redundancy may not always be possible (e.g. there may need to be a single change-over system for the main computer to the back up). Non-redundant connections between otherwise redundant and separated systems may be accepted provided that it is documented to give clear safety advantages, and that their reliability can be demonstrated and documented to the satisfaction of the administration. Such connections should be kept to an absolute minimum and made to fail to the safest condition. Failure in one system should not be transferred to the other redundant system.

International Standards

IEC 812 Analysis Techniques for system reliability – Procedure for Failure Modes and Effects Analysis (FMEA)

This is a detailed document that goes well beyond what the class societies and industry guidelines require. The following quotes from the IEC standard cover some of the more pertinent areas that it touches on that the author considers to be of particular interest.

2.2.3 USES OF FMEA – 2.2.3

Some detailed applications and uses of FMEA are listed below:

a) *to identify failures, which when they occur, have unacceptable or significant effects, and to determine the failure modes which may seriously affect the expected or required operation.*
b) *To determine the need for:*
   - *redundancy;*
   - *designing features which increase the probability of 'fail safe' outcomes of failure*

2.2.4 LIMITATIONS AND DRAWBACKS 2.2.4

FMEA is extremely efficient when it applies to the analysis of elements which causes a failure the entire system.

However, FMEA may be difficult and tedious for the case of complex systems which have multiple functions consisting of a number of components. This is because of the quantity of the of detailed systems that have to be considered. The difficulty can be increased by the number of operating modes, ------

3.6 FAILURE MODES 3.6

A failure mode is the effect by which a failure is observed in a system component.

3.6.1 Common-mode (common cause) failures (CMF) 3.6.1

In reliability analysis, it is not sufficient to consider only random and independent failures. Some 'common mode' (or common cause) failures (CMF) can occur, which cause system performance *degradation or failure through simultaneous deficiency in several system components, due to single source such as design error, human error, etc.*

4.3.1 LEVEL OF ANALYSIS 4.3.1

Basic principles for selecting the system levels for analysis depend on the results desired and the availability of design information. The following guidelines are useful:

a) the highest system level is selected from the design concept and specified output requirements;
b) the lowest level at which the analysis is effective is that level for which information is available to establish definition and description of functions. The lowest level is influenced by previous experience. Less detailed analysis can be justified for and system having a mature design, good reliability, maintainability and safety level. Conversely, greater detail and a corresponding lower system level is indicated for any newly designed system or system with unknown reliability history;

4.4.1 Failure Modes

A list of general failure modes is given in Table I.

Virtually every type of failure mode can be classified into one or more of these categories. These general failure modes are, however, too broad in scope for the definitive analysis; consequently, they are expanded as shown in Table II.

Examples of a set of general failure modes
Table I

1	Premature Operation
2	Failure to operate at a prescribed time
3	Failure to cease operation at a prescribed time
4	Failure during operation

Generic Failure Modes
Table II

1	Structural Failure (rupture)	18	False actuation
2	Physical Binding or jamming	19	Fails to stop
3	Vibration	20	Fails to start
4	Fail to remain (in position)	21	Fails to switch
5	Fails to open	22	Premature operation
6	Fails to close	23	Delayed operation
7	Fails open	24	Erroneous input (increased)
8	Fails closed	25	Erroneous input (decreased)
9	Internal leakage	26	Erroneous output (increased)
10	External Leakage	27	Erroneous output (decreased)
11	Fails out of tolerance (high)	28	Loss of input
12	Fails out of tolerance (low)	29	Loss of output
13	Inadvertent operation	30	Shorted (electrical)
14	Intermittent operation	31	Open (electrical)
15	Erratic operation	32	Leakage (electrical)
16	Erroneous indication	33	Other unique failure conditions applicable to the system characteristics, requirements and operational constraints.
17	Restricted Flow		

EXAMPLE OF A FAILURE MODE, EFFECTS AND CRITICALITY ANALYSIS WORKSHEET

Equipment Name	Function	Ident Nos	Failure Mode	Failure Cause	Local Effect	End Effect	Failure Detection	Alternative provisions	Failure Probabilty	Criticality Level	Remarks

Guidelines for DP vessels FMEA

The following seems to be a sensible set of guidelines that an owner, charterer or oil company should expect from and FMEA. Also those that produce FMEAs for DP vessels should aspire to.

Specify the following in line with the contents of this paper

FMEA Specification

Scope	Every thing that supports the positioning of the vessel, including or excluding the DP control system as the control system supplier may perform this. Define the worse case failure that the design expects.
Objectives	To find any single failure that will cause a drift off, drive off or large excursion: including a single act of mal operation. To find any single failure that exceeds the required worse case failure It must also seek out common mode (common cause) failure
Level and Format	Specify descriptive and tabular analysis with block diagrams
Trials Document	FMEA proving trials procedure requires to be produced and the trials witnessed, conducted and followed through.
Standards	Regardless of the class society being used quote ABS and DNV 2001 requirements. Also refer to IEC and IMCA guidelines
Personnel	Request the resumes of those who will be involved, ensure that they have the experience and expertise to cover all the aspects of the FMEA. Do the same for the DP control systems supplier – vet the engineer who is going to do it and get it vetted. Use a reputable consultancy that has a long history of DP. Obtain a second or even third opinion by having the FMEA reviewed by someone else with the correct qualifications.

Project Organization

Appoint an engineer to monitor the FMEA and make sure they are provided with the information in a timely fashion. Review the failure modes in the FMEA against the generic modes in the IEC requirements.

Start it early enough and budget enough to do the job right, avoid production pressures

Allow adequate time for testing on sea trials

Make sure the trials time is dedicated to the FMEA testing and that alone.

Repeat certain tests or new tests following a modification.

Retest major items every year

Expectations

Manage your expectations – FMEA is a very useful tool but it is not perfect.

Program and Costs Allow sufficient time and budget for this work – it will repay itself. Consider the possibility of having more than one FMEA performed.

Conclusions

- Prepare a specification for the FMEA with care in accordance with the guideline in this paper
- Be prepared to think and be comfortable with thinking failure
- Be involved in the process of the FMEA – in detail
- Do not just rely on the fact that as Class have approved the FMEA that it has covered everything. Obtain as many independent views as possible.
- Be prepared to spend time and money on this – it is CAPEX now with and OPEX payback later.
- Do not allow time and cost constraints to pressure you or whoever is doing the FMEA to cut corners.
- Revise and revisit after modifications.

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