DYNAMIC POSITIONING CONFERENCE
October 14-15, 2014

RELIABILITY SESSION
(Backup Paper)

Agile FMEA

By

Ajay Kaushik
(Student, Manchester Business School)

and

Prakash Chavan
(Independent Software Consultant)

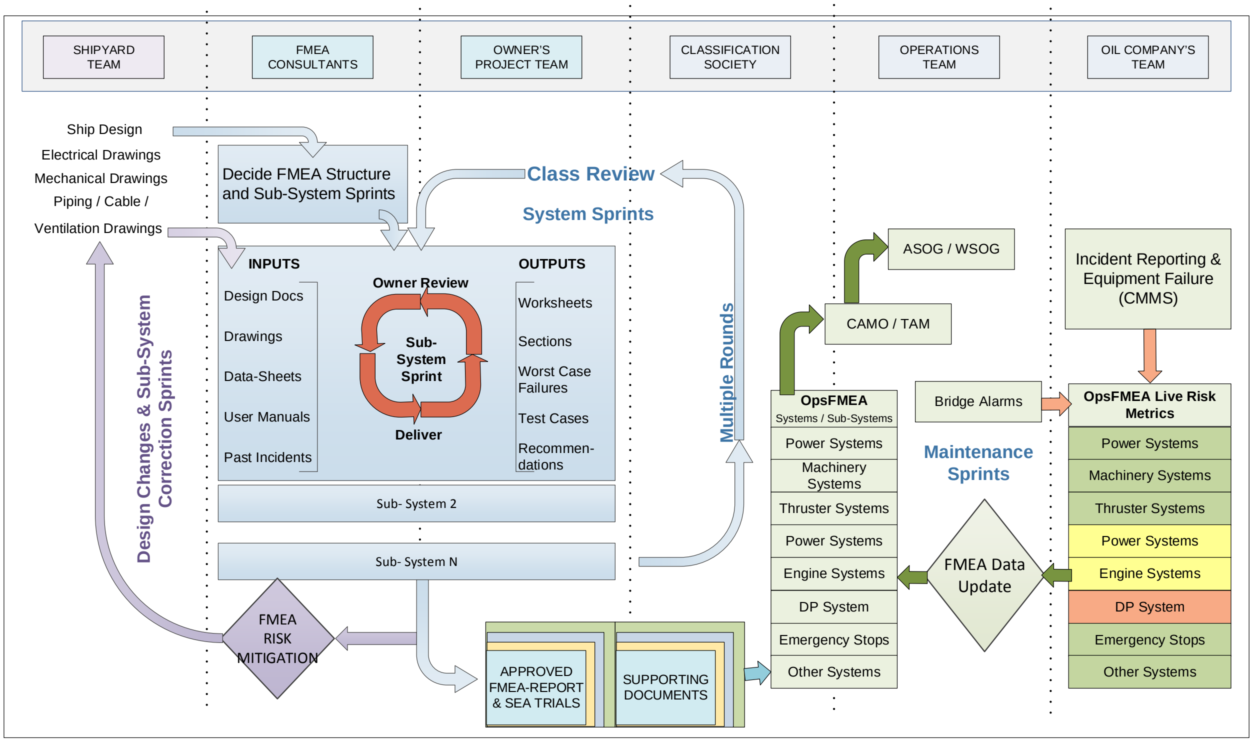
Return to Session Directory

Abstract

Scope, structure and quality in DP Failure Mode Effect Analysis (FMEA) has been a topic in focus for Marine Technological Society (MTS), IMCA and classification societies. Authors in previous MTS conferences have discussed deficiencies in DP FMEA's, while others have suggested solutions such as apt use of guidelines and templates to ensure completeness and quality of DP FMEA's. Most guidelines suggest appropriate methodology must be applied at each subsystem level to determine redundancy for analysis and sea trials test procedure to be effective. Applying methodology, following numerous guidance notes and maintaining FMEA documentation in practice can be a fairly complicated task. The FMEA, the sea trials test procedure, and the test results must also be maintained and updated in case of alterations to the system, during the operational phase.

The obvious, iterative need for FMEA document and test procedures to be maintained and updated invites the need for a proven scientific methodology such as Agile to be applied on the FMEA workflow process. This paper will suggest a FMEA workflow using agile methodology which can help not only ease and accelerate the process of creating FMEA reports but also maintain FMEA reports for life. We also discuss the potential benefits of maintained FMEA reports to act as a live vessel health indicator and objective risk management tool during the life time of the vessel.

In this paper we also propose development and use of common software to promote standardized FMEA reports and easy maintenance of DP FMEA's using Agile methodology principles. Such software shall be developed to help maintain worksheets, query records, assumption registers, test cases and their results over multiple test cycles, while providing a lifelong repository for relevant drawings and other documents.



Introduction

Modern DP vessels have become increasingly complex in their configurations and their operations. There are several layers of control systems between the operator and the machinery. Engines, generators, switchboards, thrusters and other important equipment are controlled via a network of communication mechanism between operator consoles, PLC's, microcontrollers and actuators (Phillips, Haycock, & Cargill 2010, p.3). It is therefore essential to have a multi-disciplinary engineering team working together on FMEA's of complex vessels. To write a good FMEA the team not only requires personnel who understand control system, electrical and marine systems (Phillips, Haycock, & Cargill 2010, p.3), but also requires personnel who understand the operations perspective to foresee possible failures while performing simultaneous operations. A multi-disciplinary team with different work cultures and backgrounds makes it important to follow common set of rules for document structure and content throughout a FMEA document. Good guidance has been provided by IMCA, MTS, classification societies and other key players towards objectives, application, structure and content of FMEA for redundant systems. Going into details of guidance is out of scope for this paper, however, almost all guidance points towards a well-structured, thorough and complete FMEA documentation.

A thorough and complete FMEA documentation shall also include supporting studies such as protection coordination studies, power plant stability study, voltage dip study, harmonic study and DP capability plots. It is also recommended to maintain supplementary documentation such as technical query registers, assumption registers, maintenance register, testing issues register and concerns register (Phillips, Haycock, & Cargill 2010, p.3/ 4). Relevant drawings, data-sheets, operator manuals and other documentation must also be categorized and maintained with the pertinent section or sub-system of the FMEA report.

FMEA study is not only a good way to prove fault tolerance and get DP class notation and certificate, but also a good investment for the future operation of the vessel. A thorough DP FMEA provides the following long term benefits (Harper 2008, p. 4)

- It protects the owner's assets, charterer's interests and reduces project risk. (Harper 2008, p. 4)
- A thorough FMEA, covering all eventualities, has the potential to prevent or, at a minimum, shorten downtime.
- As the FMEA trials could often be the only time the crew witness major failures in the vessel's systems, the FMEA trials are a good training tool.
- Maintaining an up-to-date FMEA avoids the need for a future expensive re-analysis of the vessel systems and rewriting of the report.
- It acts as a basis for Fault tree analysis, QRA and RAM analysis.

Ian Harper has aptly said "An FMEA is for life" (Harper 2008, p. 1).

While it is quite easy to list the numerous benefits of creating and maintaining a well-structured and thoroughly complete FMEA; creating one, on other hand, is an extremely difficult task, especially without the use of software tools. In the next sections we will try to explain how a structured, sub-system based FMEA can be easy to complete and maintain using agile philosophy.

Introduction to Agile Methodology

Agile methodology is a set of principles that ensures high quality outputs in environments subject to high levels of change and ambiguity. The Agile methodology looks to remove all cultural barriers between developer, client and end user and focuses on using the latest technology to making things simple but not simpler. Agile methods overcome rapid changes and ambiguity through adoption of an iterative development process, where deliverables are submitted in smaller delivery cycles called sprints. The focus is on completing small portions of deliverables in each sprint. At the end of each sprint the deliverables must be reviewed by a competent authority for feedback. The feedback and review ensures deliverables meet expectations with minimal costs, wasted effort and time. Part of the delight in using agile methods is the ability to escape from the boundaries of process, procedure, policy, practices and politics and do what is needed in whatever way makes the most sense to get the job done. (Parker 2013)

Agile Sprints

A sprint is a set period of time during which specific work has to be completed and made ready for review (Rouse).In our experience DP proving trials are good examples of test sprints.

1. Short period of time: The DP proving trials are completed during a set short period of time, which ranges from one day to a maximum of 3 weeks.
2. Defined scope: Test procedure and scope is well defined before the start of work.
3. Focused execution: Once a proving trial is started the resources, FMEA team, reviewers and crew, only focus on completing the tests, sometimes working for extended hours.
4. Interactive and adaptive: Vendors, class surveyor and owner representatives are at hand to review and approve test procedure and results. If needed, additional tests can be added, performed and documented to prove more capabilities of the vessel.

The FMEA document is a strong case for usage of agile methodology for the following reasons.

1. High levels of change: Numerous changes happen between original design drawings and as-built drawings for a vessel due to a plethora of reasons. These countless changes happen rapidly and in parallel for a FMEA consultant or owner's team to keep track of each and every small change.
2. Ambiguity: When planning for FMEA for the first time the consultant(s) can never be 100% sure on the exact requirements, design drawings and available support documentation for each and every sub-system. The requirements, drawings and documentation evolve during the course of the project. Agile is highly suited for such projects.
3. Cultural barriers: A FMEA team may consist of a multi-cultural team with different perceptions towards documentation, structure and work ethics.
4. Feedback: Without a thorough peer, vessel-owner and class review for each and every sub-section there is always a possibility of qualitative and quantitative deficiencies in the FMEA report.
5. Smaller deliverables: It is more efficient to review and track the delivery of contracted deliverables. For example, a class reviewer is likely to be more efficient in reviewing and finding issues in a 10 page sub-section specific FMEA report than a 1000 page overall vessel FMEA document.
6. Low wastage of time and money: Unexpected variances in FMEA reports should be easy to spot, and the detailed review comments that result should also have a fine granularity of time and cost impact. Progress should be tracked, and deviation from the project plan must be detected within days - then remediated by the team within their sprint window of two or three weeks.

It is not practicable for the class and owner representatives to oversee and review work on an everyday basis, however, review and feedback of smaller deliverables such as completed systems / sub-systems every 2-3 weeks could ensure that FMEA content meets vessel owners and class expectations without much rework. As mentioned earlier, it is more efficient to review and validate a ten page FMEA report, test cases and drawings for a sub-system compared to a thousand page full vessel FMEA with hundreds of test cases and drawings.

Active engagement of vessel owner's team in sub-section reviews helps them get acquainted with the vessel's capabilities. It also ensures that standard and quality is maintained throughout the FMEA document. The vessel owner's team and the consultants may decide to share additional data such as technical query record, assumptions register etc. with the class.

A class review can be held after completion of major system(s), which comprises of many related sub-systems, depending upon availability of reviewer. Again, it is important to record all review comments and clear each comment. The rework to clear review comments can happen in parallel with on-going FMEA activities.

Authorized access to FMEA database shall be made available to operations team and crew members of vessel once FMEA sea-trials are completed. The data repository shall also allow for annual sea-trial results to be stored each year, such that all results from different years can be compared to each other when needed. In a way, structured FMEA data repository shall be single source of truth for any FMEA related query.

Agile philosophy in DP FMEA's

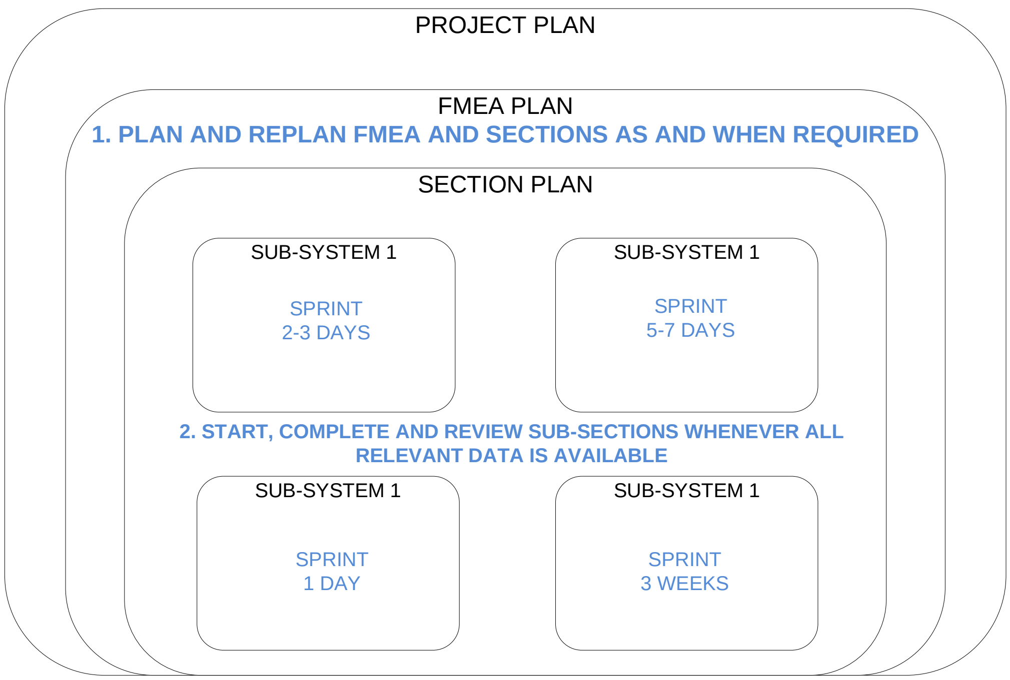


Diagram 1.1 Agile Planning for DP FMEA's

In our experience, sub-system level requirements and design frequently change within the marine industry, while the project level plan, requirements and design tend to remain stable. Therefore, we suggest a mixed agile approach to perform FMEAs.

1. Overall FMEA and large milestone plans shall be made in accordance with top level project plans in shipyards, with section level scheduling for the succeeding few weeks or months. (Project management philosophy)
2. Sub-Systems shall be planned, executed and reviewed in sprints using agile philosophy.
    a. Before starting a sub-system sprint, availability of all relevant documents and drawings must be ensured such that there is no waiting time during the sprint.
    b. A sprint can be divided into three distinct phases:
        i. Sprint planning: This phase should not take more than about 10% of the sprint time in most cases. This phase identifies the various deliverables: documents, worksheets, tests etc to be produced at the end of the sprint.

ii. Sprint execution: This phase should take about 80% of the sprint time. In this the actual content / deliverables, identified in the planning phase, will be created.
iii. Sprint review: This phase should take about 10% of the sprint time and shall involve vessel owner's representative reviewing, giving feedback and approving the content created in the sprint.

c. If any content / deliverable was not created due to any reason, such as incomplete documentation, aggressive timelines or external factors outside the control of the sprint team, it is called as Sprint debt. Such a debt must be noted and paid for at some stage in order to improve the quality and effectiveness of the FMEA content.
d. A sub-system must be completed in all aspects during a sprint such as delivery of all sections, worksheets, boundary diagrams, test cases, recommendations, conclusions and updating relevant query registers, assumption registers etc.
e. A sub-system shall not be marked as completed until reviewed by owners or class representatives.
   i. The sub-system may be marked as complete if the sprint debt is non-critical and noted.
   ii. Once reviewed all review comments must be recorded and satisfied before marking the section complete.

The diagram 1.2 illustrates the process of completing a sub-section in a DP FMEA.

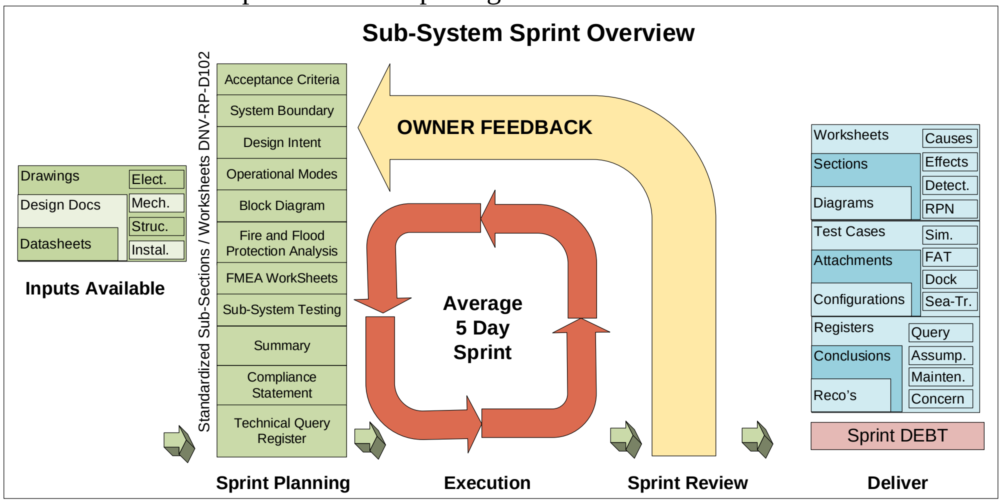


Diagram 1.2 Sub-section sprint cycle
(Adapted from DNV-RP-D102, 2012)

Each sprint shall have its own tasks list, identified during sprint planning, which shall consist of different sections and worksheets necessary for a given sub-system or component. Number of sections, their headings and content may depend on consultant, vessel owner, template used (Hodge & Kerr 2012, p.7) or guidance followed for the FMEA document. After reviewing necessary design documentation and drawings, the FMEA consultant shall complete all sections during sprint execution.

While completing a section the consultant must also complete the following tasks.

1. Add necessary block and boundary diagrams associated with the section (DNV-RP-D102, 2012).
2. Attach relevant design documentation and drawings associated with the section.
3. Add necessary test cases to test the sub-system, associate relevant alarm code and expected results (DNV-RP-D102, 2012).
4. Append technical query register, assumptions register, maintenance register and concerns register as applicable (Phillips, Haycock, & Cargill 2010, p.3).

5. Add design recommendations and operations recommendations (DNV-RP-D102, 2012).
6. Add necessary worksheets with updated fields for causes, effects and detection (DNV-RP-D102, 2012).

Different members of the FMEA team can work on their respective sub-system sprints in parallel to each other and collaborate towards completion of overall FMEA report as illustrated in diagram 1.3.

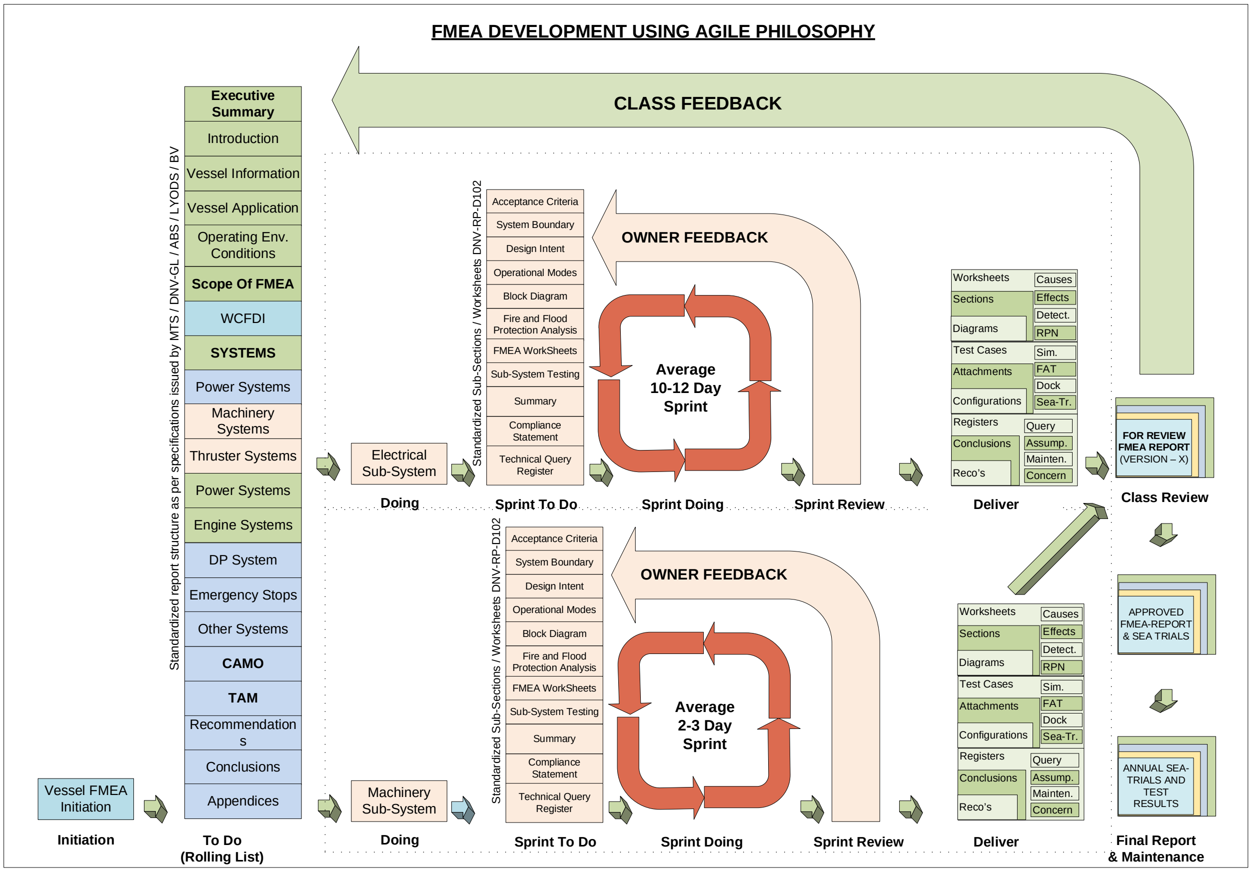


Diagram – 1.3Parallel sprints in DP FMEA's
(Adapted from DNV-RP-D102, 2012)

For agile methodology to be effective for DP FMEA's, it is essential to use structured FMEA repository such that all documents created are stored in right system -> sub-system -> sections -> sub-sections. We will discuss details of FMEA repository and software tool in-detail in later sections of this document. Each sub-system shall consist of sub-system specific sections, worksheets, boundary diagrams, test cases, attachments, configurations, registers, conclusions, recommendations and list of review comments by owner and class representatives.

Software for DP FMEA

Dynamic positioning FMEA's are a very different when compared to FMEA methodologies used in other industries such as automotive industry and aerospace industry. Guidelines provided by MTS, IMCA and classification societies all point towards complicated requirements of FMEA which may require formatted text, worksheets, test cases and their results, and lists of questions & their answers, recommendations and operations advice. There is also the need for a document management system to manage different versions of FMEA document and related versions of design documentation. In near future, there may also be the need to integrate electronic templates and sample data provided by various classification societies and forums. Basic, but essential, software tools such as Microsoft excel and word may not be sufficiently equipped to cater to all these needs. A DP FMEA specific software will help the FMEA experts to focus on creating content rather than worry about structure and acquiring advanced excel and word skills.

There is also a need for FMEA repository to be maintained and supported by easy to use user interface software. We suggest design and development of DP / Marine industry specific software which can aid FMEA consultants to use guidelines or templates provided by MTS, IMCA or classification societies to provide standardized FMEA reports and encourage high quality. Use of common and possibly free software across industry will also make it easier for consultants, vessel owners, surveyors and crew members to understand and quickly contribute to FMEA's made by other consultants.

It may also be more practical to maintain FMEA repository and common software onboard vessels for the following reasons

- Easy maintenance and update of FMEA for years to come, synchronizing with FMEA content stored at shore-offices.
- Electronic FMEA repository could act as virtual document library for all design / as-built drawings, equipment data sheets and manuals onboard vessels and authorized access, possibly even on hand-held devices.
- Structured electronic FMEA repository will be easy to search and sort for vessel operators making it easy to troubleshoot alarms and train new crew members.
- The electronic FMEA repository can also ease creation, modification and maintenance of critical area mode of operation (CAMO) and task appropriate mode (TAM) documents (IMCA M220, 2012 & MTS DP Operations Guidance, 2012) from the relevant data available within 'worst case failure design intent' or other specific section of sub-systems.
- These auto-generated CAMO and TAM documents may in turn result in easy creation, modification and maintenance for ASOG / WSOG documents on the repository.

In theory, the incident reporting and equipment failure recording system of continuous machinery maintenance system (CMMS) can be connected with the electronic FMEA document such that all incidents and equipment failures can be linked and recorded with each subsystem and systems. Such a linking and recording of incidents and equipment failures over a period of time would not only reflect upon the qualitative and quantitative effectiveness of the original FMEA report but also catalyst improvement in vessel operations planning, documentation and maintenance.

The FMEA repository may also be paired with bridge alarm management (BAM) system to log and record all bridge alarms for producing a sub-section categorized risk report to help manage risk more objectively onboard vessels. This data can be used to generate various risk matrices to do proactive risk management rather than reactive risk management as shown in diagram 1.4. We will present a mathematical model for achieving this in a separate paper.

'Risk repository' and 'FMEA repository' terms may be used interchangeably, as the repository shall not only help manage FMEA's but also facilitate other risk management activities. In our opinion, sub-section structured FMEA repository will be the core base on which any such objective risk management activities can be performed. Such a repository shall not only focus on establishing and proving redundancy but also focus on other risk analysis processes such as help accelerate the process of live Quantitative Risk Analysis (QRA) and Reliability, Availability, Maintainability (RAM) analysis. Such a system shall also work in collaboration with Continuous Machinery Management System (CMMS) or Rig Management System (RMS) depending on specific vessel or company and work in parallel with Health and Safety

Executive's (HSE) verification requirements for safety critical elements (SCEs) obtained from an independent competent person (ICP).

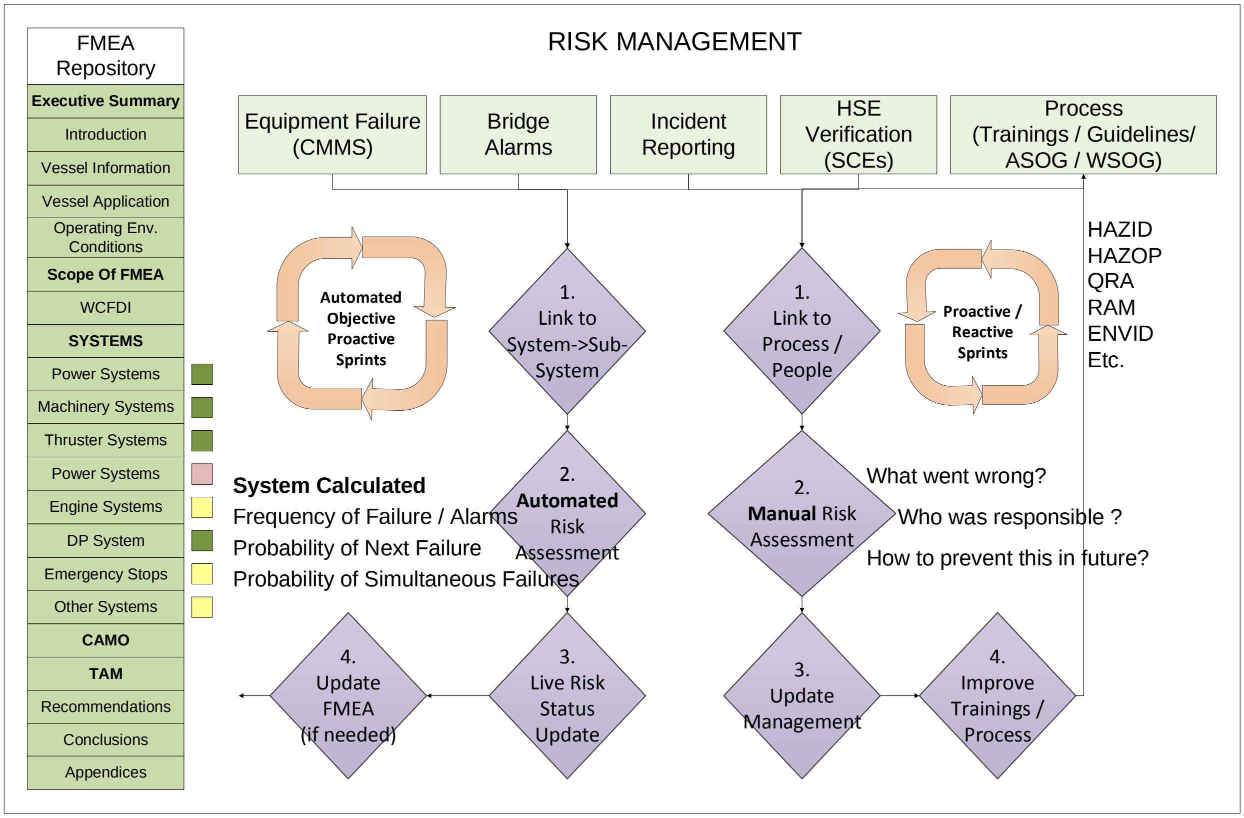


Diagram 1.4: Automated and manual risk management

Design of DP / Marine specific FMEA software

Software which helps apply agile philosophies to DP FMEAs will combine agile philosophy with architecture best practices. Therefore, to develop such software we propose following key concepts to be observed:

Identify the key domain entities and their relationships

Some of these key concepts in FMEA domain are: System, sub-system, Worksheet, Test, Cause, Effect, Detection, WCFDI and Query Register etc.

It is important to know that the relationships are not just about cardinalities between entities but also about the semantic relationship between the entities. For example, the cardinality between Worksheet and Cause is one-to-many. However, the semantic relationship between Worksheet and Cause is the various ways in which the particular effect identified in the worksheet can occur. The software should make all such semantic relationships obvious and natural to use and work with and hide cardinalities to the extent possible.

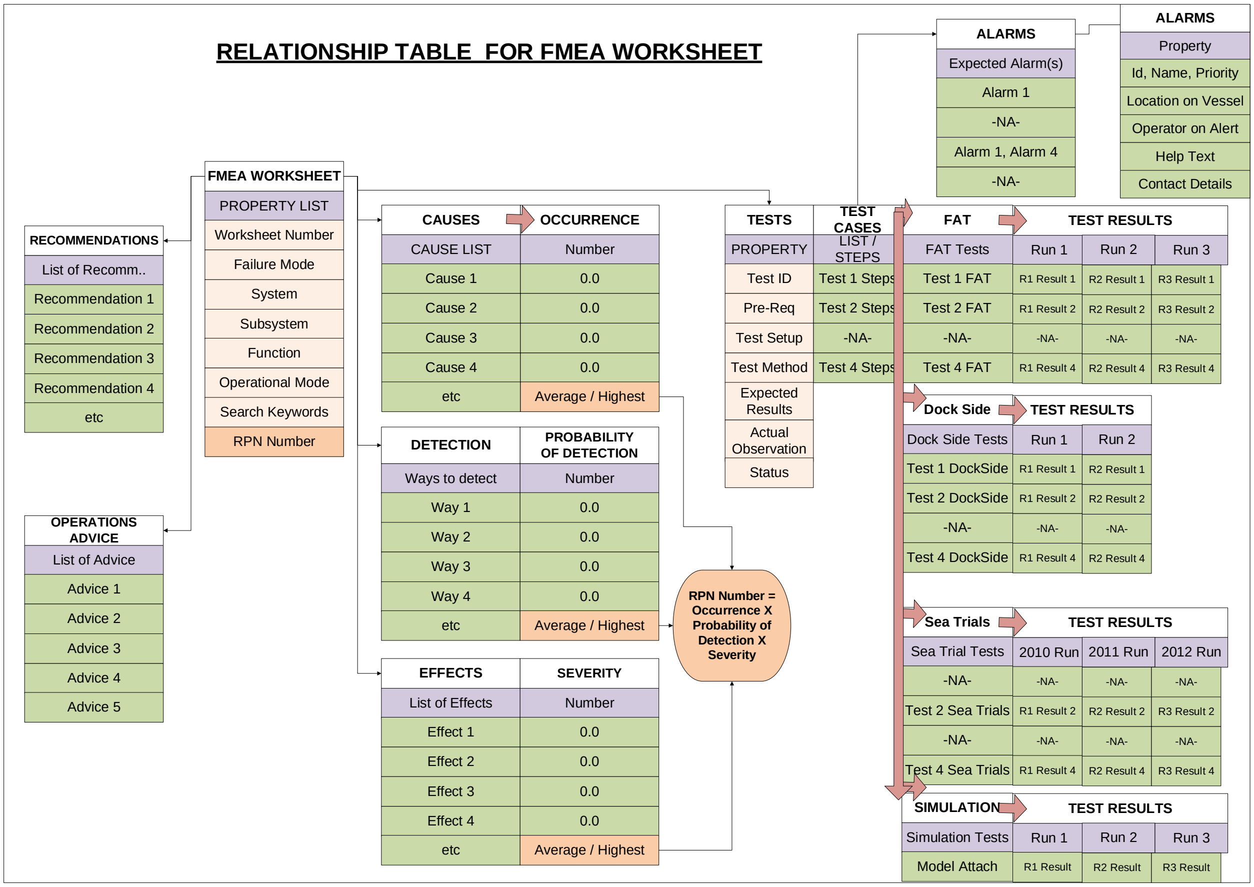


Diagram 1.5: Example relationship diagram

Iterative development of content over multiple sprints

An essential aspect of agile is iterative development of content spanning over multiple iterations called sprints. Iterative development also enables early failure in the event the current approach is not ideal and needs re-evaluation. This can be achieved by the software in many ways: By providing ability to breakdown FMEA into smaller chunks like systems and sub-systems; By providing good agile planning, execution, and tracking capabilities; and By providing versioning capabilities to develop content over a period of time.

Reusability

FMEA software should make it possible to re-use the best content and structure, created for one FMEA, to be re-used in part or entirety in another FMEA project. This can be achieved in following ways:

- *A template based approach to FMEA document structure:* A FMEA template will capture the arrangement of FMEA document content in re-usable manner. A template can be created once and re-used many times to create FMEA documents.
- *Re-using the section/worksheet/tests contents in another FMEA:* This reusability can be in many ways. Either entire or part of the FMEA section / worksheet / tests, or a version, can be reused in another FMEA or adapted and reused in another FMEA. Or an existing FMEA section / worksheet / test can be referred to develop new section / worksheet / test etc.

Adapt well to change

Everyone has heard the phrase, “the only thing constant is change”. While this is true for software, it is also true for the content. Various societies from time to time will propose new additions and new ways of doing FMEAs. It is therefore important that the software can help FMEA consultants and companies to adapt to these changes in an accelerated manner. A FMEA software can achieve this by:

- *Evolving template(s):* The FMEA best practices as proposed by various societies and leaders in FMEA will continue to evolve to reflect changing dynamics. A software based template which reflects the best practices in the industry will adapting to change easier.
- *Evolving content:* The best practices as proposed by various societies and FMEA leaders will also related to the content of the FMEAs. A software based content management will make it possible to plan, manage and track an improving and evolving content vis-à-vis FMEAs.

Support for multiple personas

A software system can support multiple personas and display content and information according to the persona using the system. For example, a FMEA consultant will be interested in the FMEA document, section, systems, subsystems and worksheets etc. However, an FMEA administrative persona would be more interested in creating good FMEA templates to set standards to be followed in all FMEAs within an organization. A Vessel owner persona might be interested in view which shows quality and completeness of the FMEA via charts and matrices. A war room like operator observing remotely multiple ships at the same time might be interested in the view of the alarms and health of various systems on the vessels operating in the sea.

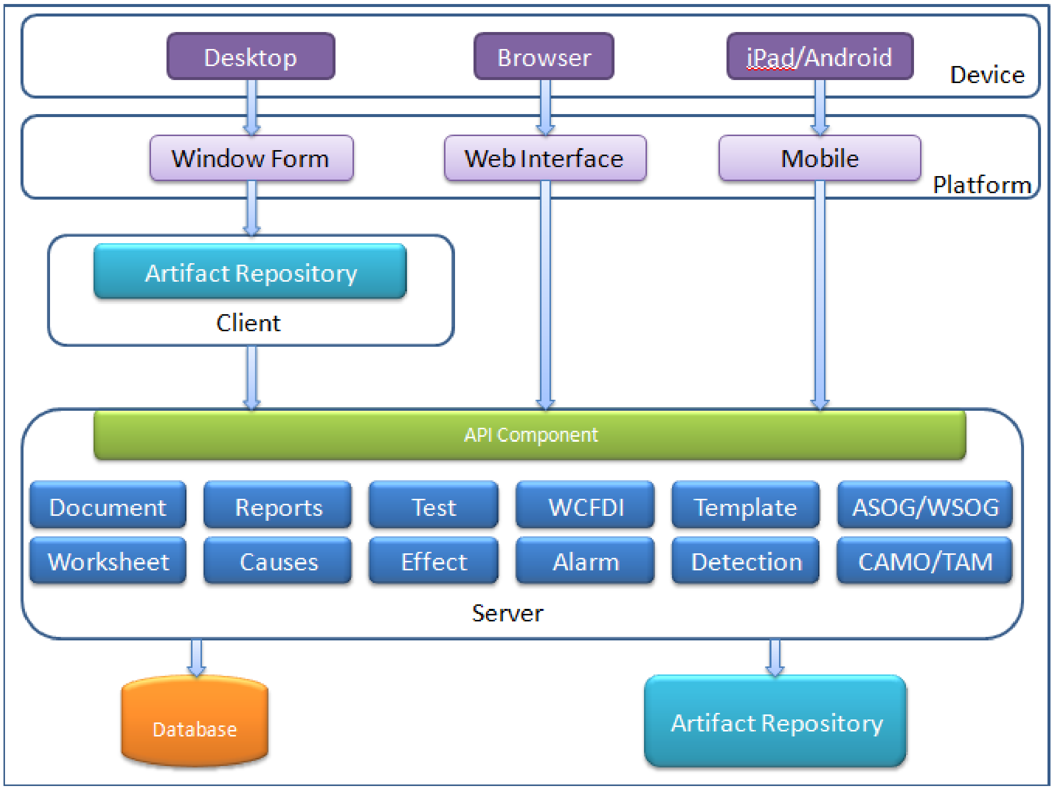


Figure 1.6 Proposed Software Architecture

Be Enterprise and SaaS Ready

In these times of Enterprise and Cloud software, it is imperative that the architecture of the DP FMEA software is both Enterprise and SaaS ready.

Enterprise ready software is deployed in a large enterprise used simultaneously by multiple users. This kind of usage promotes collaboration within the enterprise, gives complete control of hardware, data and processes to the enterprises, and is hosted within the enterprise network. This kind of deployment is most preferred by large enterprises.

SaaS ready software architecture is multi-tenant in nature. The software is offered as a cloud based service where the service provider manages the hardware and software. The data is still owned by the users. This service is available to users with internet connection anywhere on the globe. The users are either individual consultants or SMBs who don't want the hassle of managing and maintaining a deployment of their own.

Conclusion

The need for improving the quality of DP FMEA has been highlighted for past few years. However, now there is an opportunity to do a quantum jump in the DP FMEAs. Using agile methodology concepts, customizing and applying them for DP FMEAs will result in an easy and robust process which would ensure consistent, structured and quality FMEAs, useful not only to get class certification but also prove to be a real asset for the entire life of the vessel. Furthermore, use of software system to help create, maintain and use the DP FMEA content would prove beneficial in training the crew w.r.t. the vessel's capabilities, act as a single source of truth, and integrated with other on-vessel systems would act as a proactive, real-time operations and risk management system.

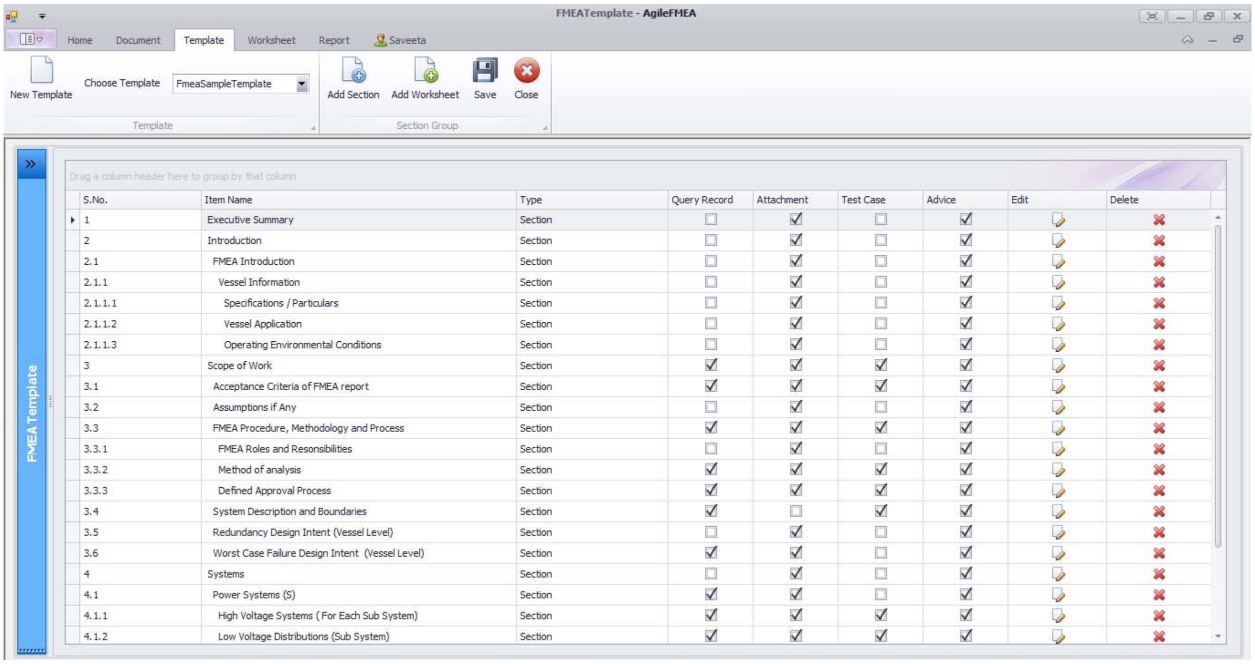
Further research could be undertaken on setting up risk war-rooms at vessel owners and oil companies for real-time monitoring of changing risk scenarios at their fleets and oil-fields respectively. However, any such risk war room will need live QRA data to be provided by software system onboard vessels, which provides online updates for both automated and manual risk assessment. We believe that FMEA repository can be the starting point of moving towards such objective, centralized monitoring and control.

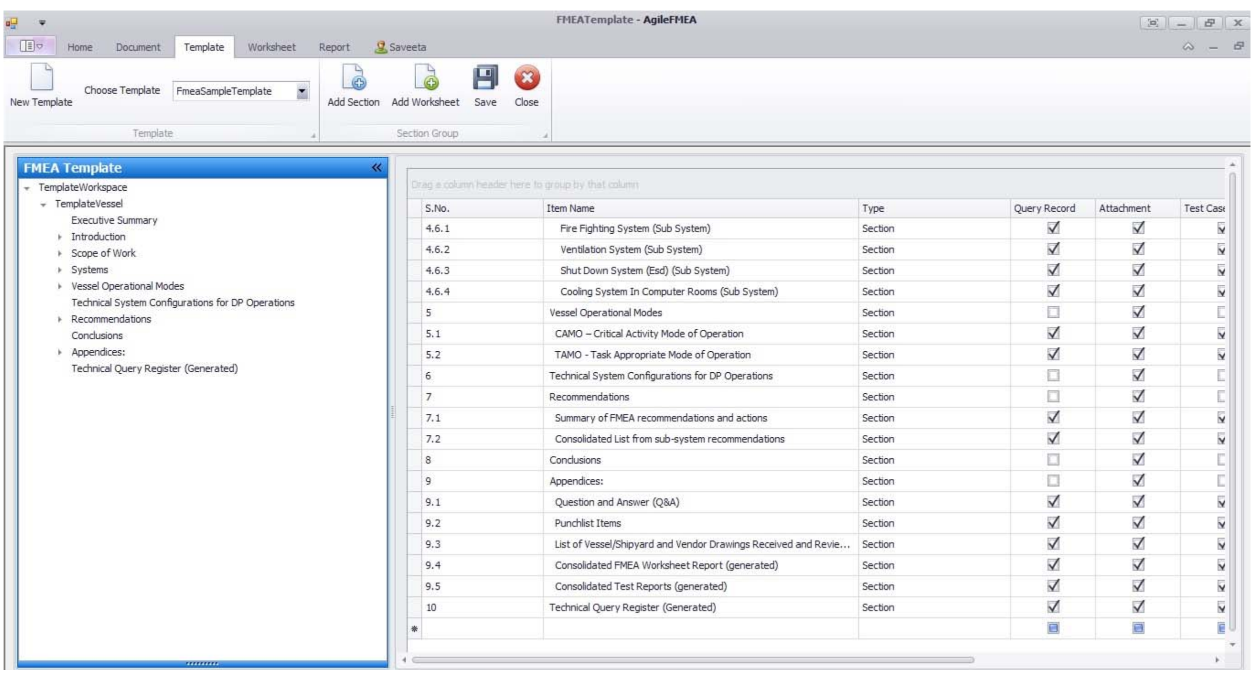
References

MTS DP Operations Guidance, September 2012, Part 1
MTS DP Operations Guidance, September 2012, Part 2 – Appendix 1 – MODUs
IMCA M 200, November 2012, Guidance on Operational Activity Planning
IMCA M178, April 2005, FMEA Management Guide
DNV-RP-D102, January 2012, Recommended Practice, Failure Mode and Effect Analysis (FMEA) of Redundant Systems
HSE Offshore Information Sheet No. 1/2012, August 2012, Available at: <http://www.hse.gov.uk/offshore/infosheets/is1-2012.htm> [Accessed on 10-Sept-2014]
Doug Phillips, Brian Haycock &Steven Cargill, October 2010, FMEA Failed to Meet Expectations Again (Again?)
Russell Hodge & Paul D Kerr, October 2012, Template for FMEA Quality Improvement
Ian Harper, October 2008, An FMEA is for life
Margaret Rouse, Available at: <http://searchsoftwarequality.techtarget.com/definition/Scrum-sprint> [Accessed on 10-Sept-2014]
Kevin Parker, Available at: <http://fcw.com/articles/2013/07/15/agile-development-deliver.aspx> [Accessed on 10-Sept-2014]

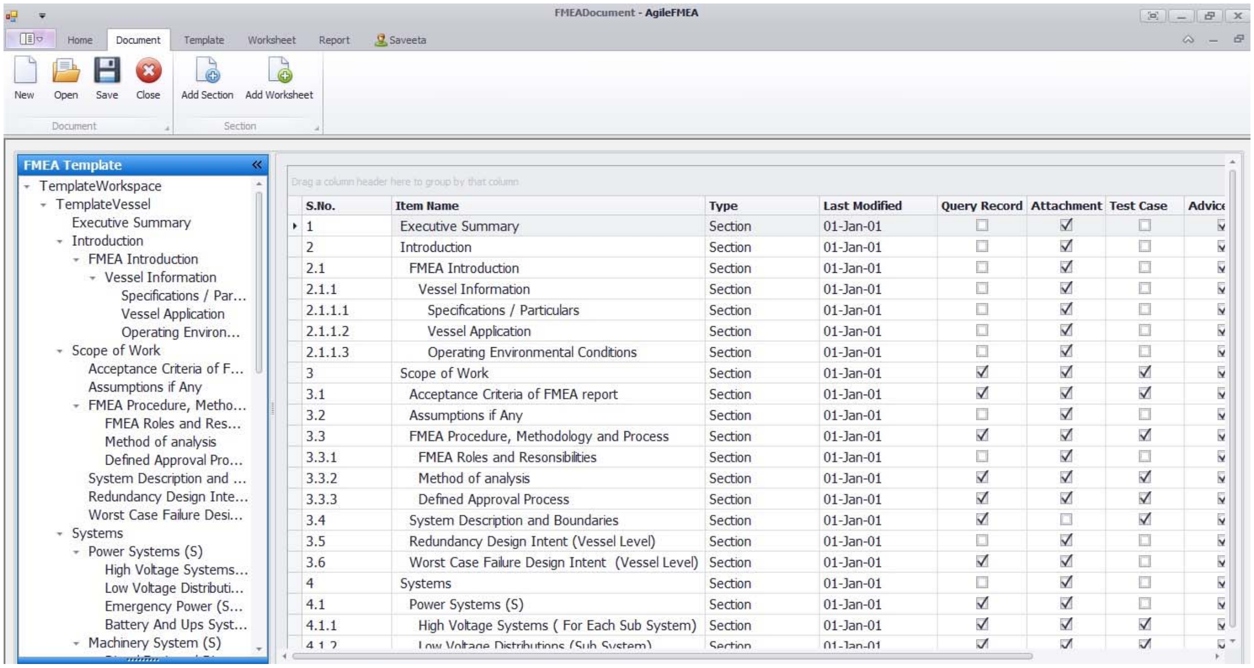
Appendix A

1.0 FMEA templates – Contains only structure and attributes, no data.

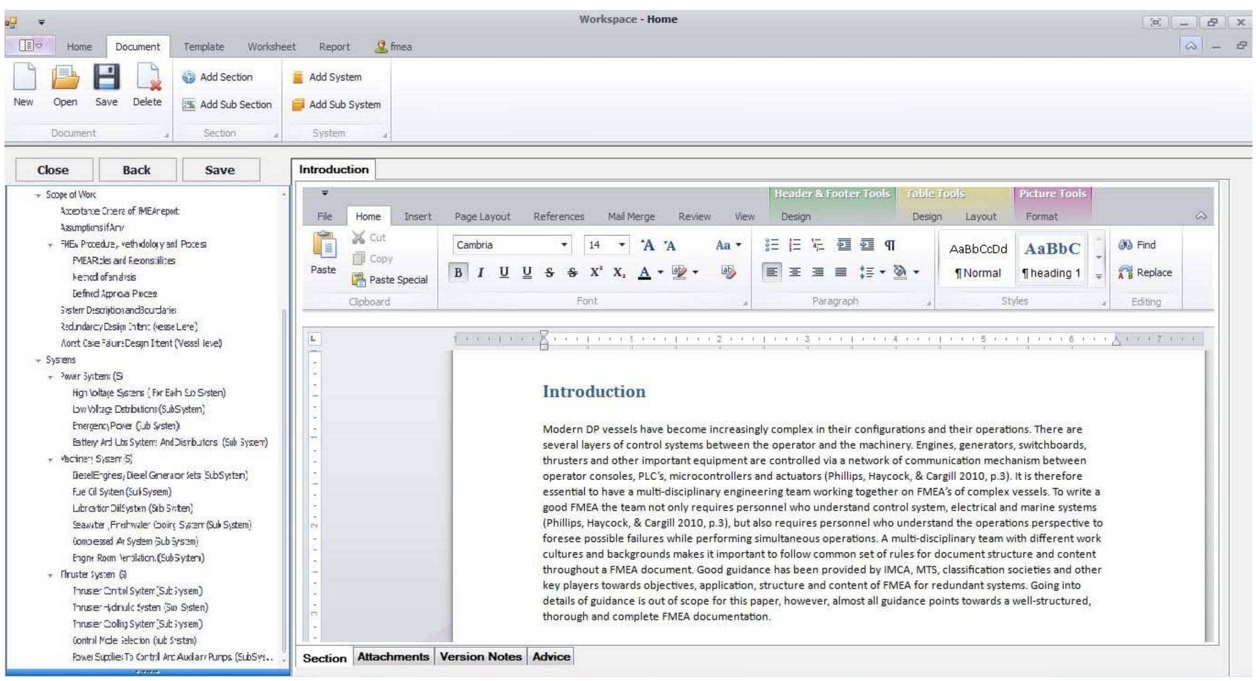




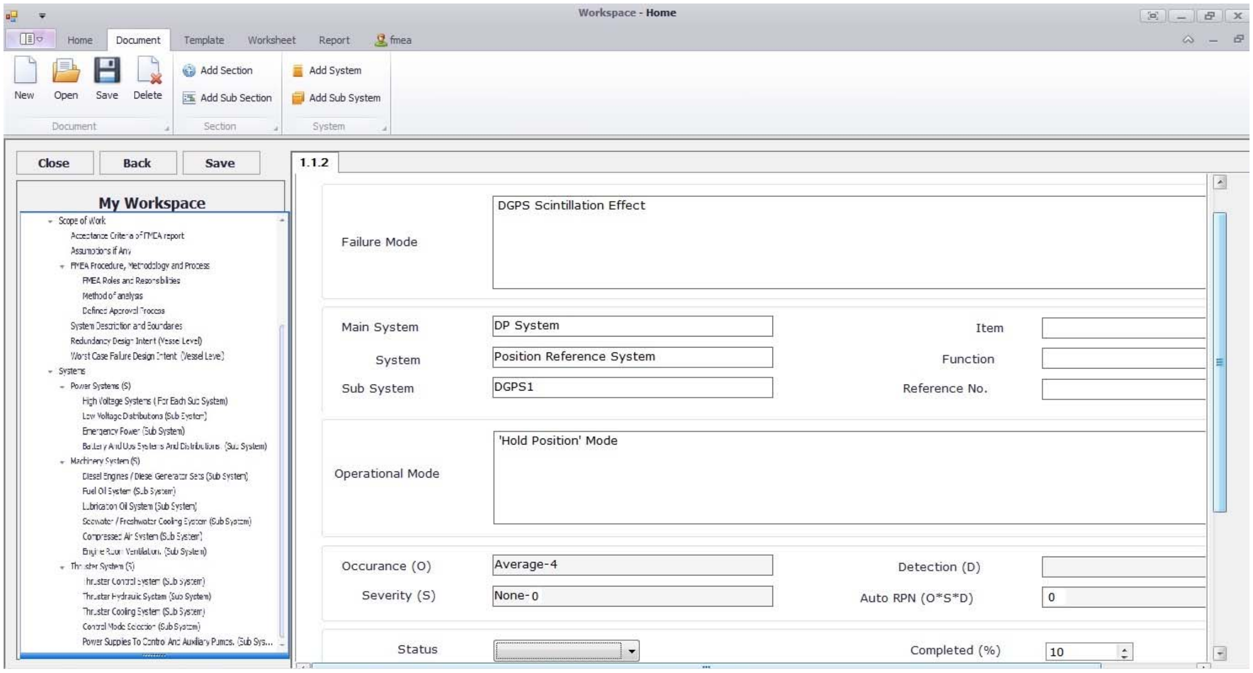
2.0 Example FMEA document created from template



3.0 Sections within a sub-system



4.0 Example worksheet



5.0 Test cases