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Lessons from Risk Assessment of 6th Generation Drill-ships and Sem-Submersibles

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Abstract

Building a deep-water drilling rig that incorporates the latest technology while meeting internal requirements, client specifications, and budget constraints, can be a daunting challenge. Doing so in a post-Macondo environment with a shortage of qualified personnel to man the rig adds even more obstacles to overcome. Ensuring that a variety of rig systems supplied by different vendors will be integrated into a workable rig that is properly maintained is another task for the drilling contractor.

The risk management plan was implemented in the form of individual risk assessments focused on each of various systems utilizing primarily the failure modes effects and criticality (FMECA) methodology. It can be quite surprising to evaluate the results of these sessions and realize how powerful these tools can be and how effective they can be in identifying potential faults and weaknesses in the systems. Maintaining a global view of the rig while carrying out the individual risk assessments was critical to ensure overall integration of the systems.

The paper results will highlight examples of findings across a wide spectrum of rig systems, from the cooling water system of active heave drawworks braking resistors to NOVEC release on an F&G detection system to challenges on a pipe handling system. Each example will have its own unique circumstances, but they all highlight the importance and value of implementing an effective risk management strategy.

This paper also demonstrates that implementing a risk management plan during the design and construction of the rigs can help reduce risks associated with major accidents and downtime. This can be accomplished by applying the results of the risk assessments into training of personnel, updating of operational procedures, updating of maintenance procedures, modifying designs, changing control systems and re-programming software. This paper presents the results of risk

assessments applied to semi-submersibles and drill-ships, all 6th generation deep-water drilling rigs.

Keywords: Risk Assessment, Risk Management, Mechanical Integrity, Human Factors, Interfaces, Training and Performance, FMEA

1 Introduction

Building a deep-water rig that incorporates the latest innovations of technology and automation is a challenge that requires planning, coordination, and a thorough understanding of the limitations of people and machines. Implementing a risk assessment and management program is an essential part of the rig building process.

Figure 1 - 6th Generation Drill ships

Consider some of the challenges facing a drilling contractor in building a modern 6th generation ultra-deep-water rig:

- Highly complex systems designed and manufactured by multiple vendors
- Integrating complex systems with the shipyard-built systems
- Highly automated systems that require coordination and integration
- Highly automated systems that need to be operated by rig personnel

- Highly automated systems that need to be maintained (and, if required, repaired) by rig personnel
- Maximize up-time and minimize downtime while maintaining safety and equipment integrity

2 Methodology

2.1 Risk Assessment Objective

The primary objective of a risk assessment is to identify, understand, and implement measures to mitigate the risks associated with the design and operation of the rig, systems, and equipment.

Risk assessment is a very broad term that is used in many different contexts: financial, technical, project management, design, manufacturing, etc. It is important to define what we mean when use the term *risk assessment*. In our context, the following broad steps comprise the risk assessment process:

1. Hazard Assessment
2. Risk Evaluation
3. Risk Mitigation

It is not our objective to explain in detail the risk management strategy that can be implemented; a risk assessment is one of the steps in the process. In general, this paper presents the risk assessment process based on numerous past projects and experiences. The primary tool utilized was the failure modes, effects and criticality assessment (FMECA). This is a well-established methodology in the oil and gas industry that was originally developed for use in the aerospace (and military) industry to analyse complex systems. The methodology was modified to suit the particular needs of the systems and situations to be reviewed for the project. This modification to the methodology included heavy emphasis on preparation, participation, and technical content, particularly in the function description of components. The following figure portrays the FMECA process:

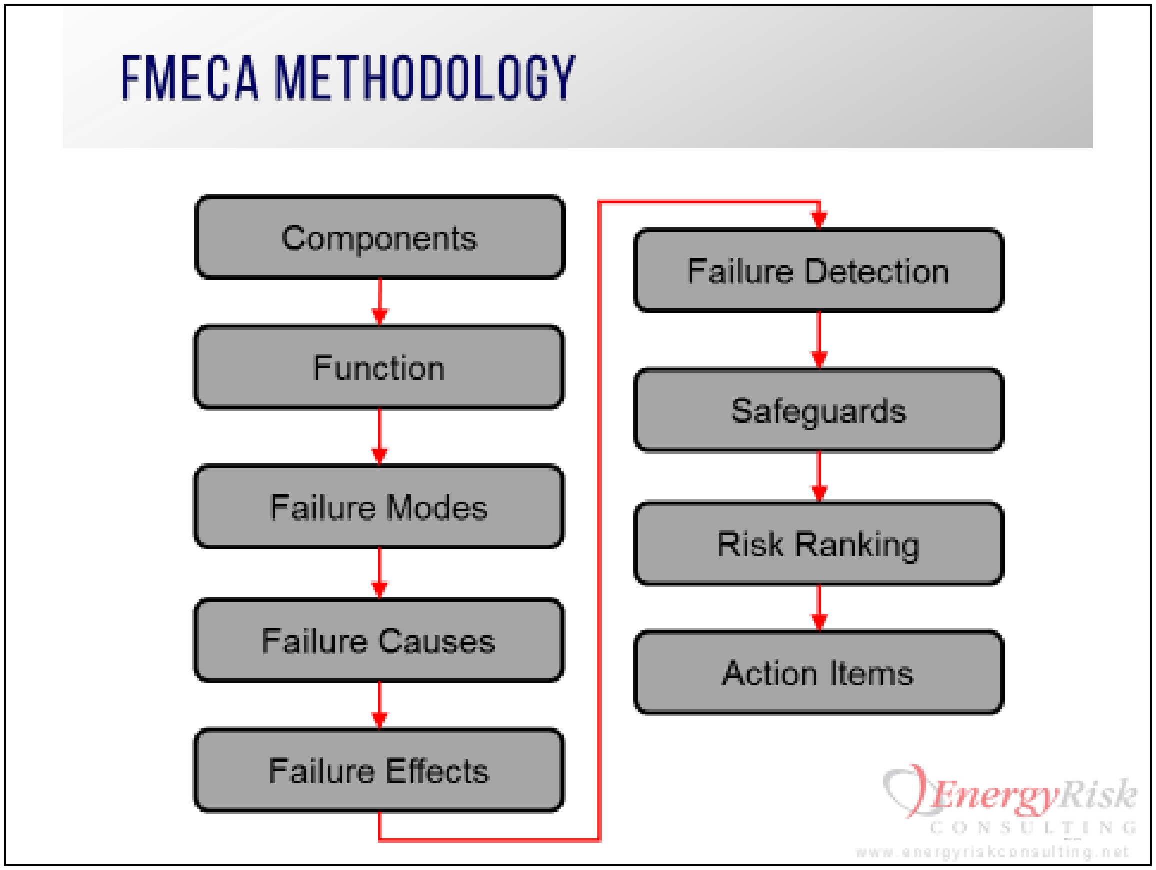

Figure 2 Typical FMECA Methodology

The following typical questions were asked during the risk assessment:

- What are the major components in the system?
- How can those components fail?
- What root causes create those failures?
- How can those failures affect the performance of the component?
- How can those failures affect the performance of the system?
- How can those failures affect the performance of the rig?
- What can be done to eliminate the failure?
- What can be done to minimize the likelihood of the failure occurring?
- What can be done to reduce the consequences if the failure occurs?
- Can you detect the failure? (Is it a hidden failure?)
- What is the required maintenance and inspection on the system components?
- How can you improve the system performance?

2.2 Level of Detail

The process emphasizes preparation, participation, and technical content. This approach maximizes the value of the participants' time in the session and extracted the most relevant information via productive discussions throughout the assessment. In an attempt to demonstrate the level of detail that is involved, the following figure shows a sample truncated line item in the FMECA spreadsheet describing a temperature transmitter on an electric motor. This is presented to indicate the detailed description and emphasis on technical content in the sessions. It also shows the level of preparation that is required to maximize effectiveness:

<table>
<tr><th>COMPONENT</th><th>FUNCTION</th><th>FAILURE MODE</th><th>FAILURE CAUSE</th></tr>
<tr><td rowspan="2">TRANSMITTER TEMPERATURE - MOTOR #1</td><td rowspan="2">There are two RTD's (Resistance Temperature Detector), one of which is a spare, for each motor winding. There are 3 temperature sensors used per motor. Any one sensor with a temperature above 160C generates an alarm. Two sensors above 180C generates a trip of the affected motor.

With hi-hi of two sensors:

1. AHC: heave compensation continues, affected motor will trip
2. non AHC: ALL motors (including affected motor) are used to slow down the drawworks, and zero speed is set. Mechanical brakes are set.

The range of the temperature sensor is 0C to 200C. It generates a 4-20mA signal. This signal is sent to DW Control System PLC. The PLC performs all processing on the signals other than validation of signal integrity. The temperature transmitter has a loop monitoring function that monitors the element (RTD) status. If the transmitter detects a failure of the RTD then a high amp signal (greater than 20mA) is sent to the DW Control System PLC.</td><td>Loss of signal</td><td>Wire break, termination failure, transmitter failure</td></tr>
<tr><td>Erroneous signal</td><td>Transmitter failure, EMI</td></tr>
</table>

Figure 3 FMECA Spreadsheet Sample

2.3 Bottom Up Approach

It is worth noting that the FMECA approach used is a bottom up approach. To ensure that systems are integrated correctly, we emphasized that failure escalation from component to sub-system to system to the entire rig.

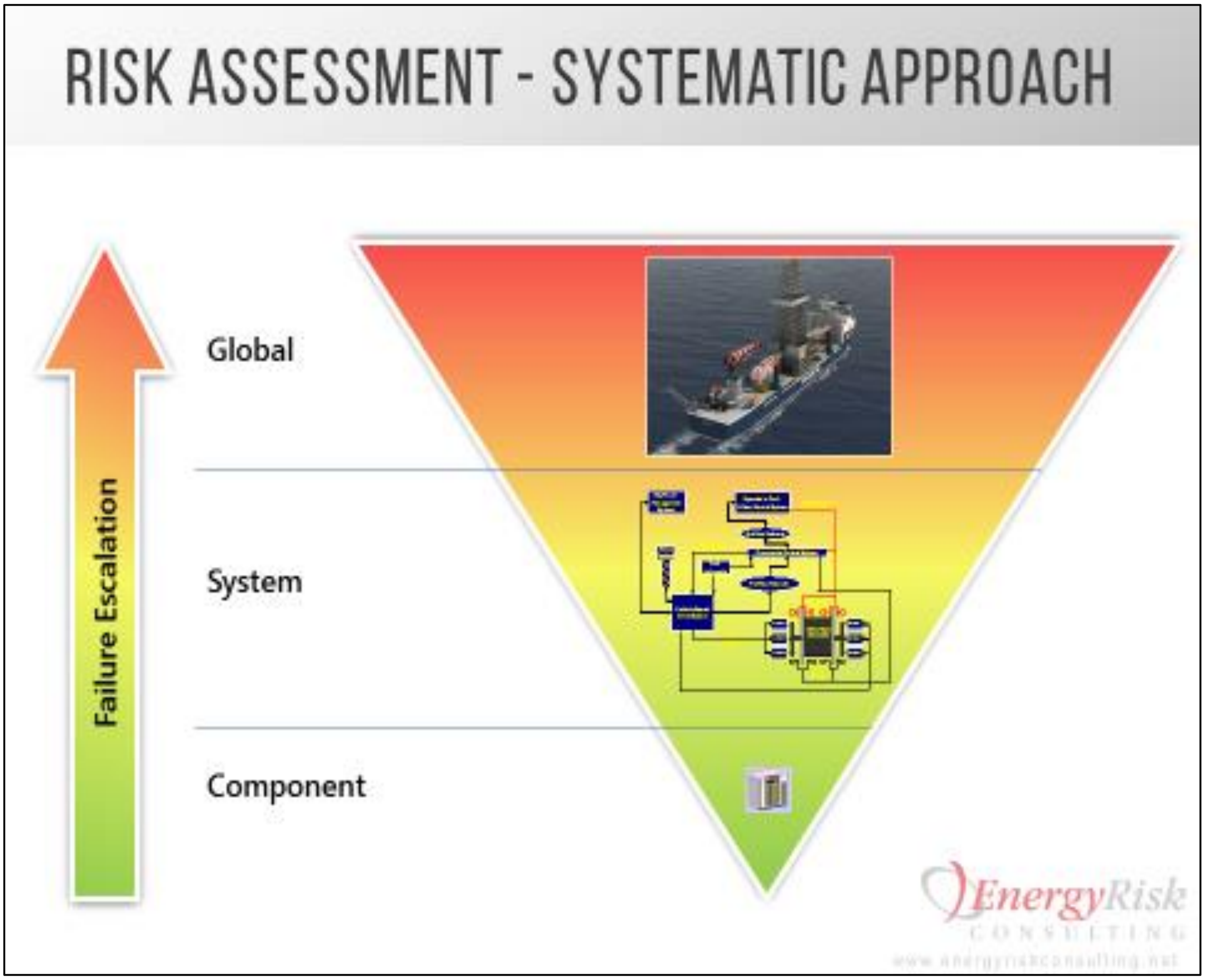

Figure 4 Bottom Up Approach

Participation was also a very important factor in ensuring the success of the risk assessment. We are referring to participation from the equipment manufacturer and the rig crews (driller, assistant driller, mechanic, electrician, chief engineer, tool pusher, etc.). Determining the level of participation and the personnel to participate is based on the system or systems being analysed. Obviously, systems that are heavy on electrical and electronic components, such as the drilling control network or anti-collision system, will involve the electrical disciplines on the rig. Participation of the rig crew also serves as an excellent training and educational opportunity. As the components, systems, and the rig is being analysed, detailed discussions inevitably arise leading to improved understanding of the design, operation, and maintenance of the systems. It also potentially leads to improvements in the design based on the feedback from the equipment users to the manufacturer.

Timing of the risk assessment is a critical factor in ensuring success and maximum benefit. We are referring to the timeframe between detailed design and manufacturing. During this time, there is enough detail in the design to have a thorough and proper analysis, yet it is not too late (or too expensive) to modify the design should any flaws be discovered, improvements suggested, or recommendations proposed.

2.4 Hierarchy of Approach

Once the hazard identification and risk evaluation have been carried out, the final step in the process is to implement mitigations to address the identified risks. Generally, the hierarchy of approach is:

A. Implement measures to *eliminate the risks*
B. Implement measures to *reduce the likelihood* of the risks
C. Implement measures to *reduce the consequence*

Risk Elimination - eliminating the identified risk can occur in many forms, and via many techniques and processes. This can be accomplished through physical changes such as structural design modifications or adding or removing components (such as valves, sensors, pumps, etc.). There are numerous possibilities and options. It is important to note here, however, that implemented changes need to be incorporated in the risk assessment, otherwise there is a danger in introducing new hazards that have not been evaluated.

Risk Likelihood Reduction - implementing measures to reduce the likelihood of events occurring can also be carried out in different ways. Examples include increased maintenance and inspection frequency. Another technique could be to increase capacity to a particular system (such as additional pump to a hydraulic system). Operational procedures can be updated or modified to reduce the load on a system, such the electrical generation on the rig.

Risk Consequence Reduction - reducing the consequence can be accomplished by providing additional components (reduction in downtime due to inadequate spares), increased training (leading to faster troubleshooting and fixing of failures), increased in maintenance and inspection, testing frequency, etc.

The implementation of recommendations can take the form of:

- System design changes
- Software changes
- Changes to FAT (factory acceptance testing)
- Changes to commissioning testing
- Changes to SIT (system integration testing)
- Updates of the critical spare parts list
- Update of maintenance procedures
- Update of operational procedures

3 RISK ASSESSMENT EXAMPLES:

The following three (3) example findings were chosen in an attempt to demonstrate the benefit of carrying out an FMECA-based risk assessment:

A. Water Mist System Redundancy
B. Pipe Handling System Failure Escalation
C. Anti-Collision System Fault Leading to Drawworks Stoppage

3.1 Water Mist System Redundancy

In this example based on a new-build rig, a risk assessment was carried out on the fire-fighting system. Included in the assessment was the water mist system covering several critical spaces (in this case the engine room). During the FMECA, it was identified that two pumps were installed in the system, one as primary and one as a backup. After further scrutiny, however, the FMECA team discovered that there was no automatic switch-over to the backup pump. So, in a fire scenario, a failure of the primary pump would have required that rig personnel *manually* switch over to the backup pump. This design was, of course, found to be less than ideal considering the potential for fire and the criticality of the system. The result was a relatively minor modification to have an automatic switch-over system installed. This minor modification, however, resulted in a significant reduction in risk by substantially increasing the expected availability of a critical fire-fighting system.

3.2 Pipe Handling System Failure Escalation

This example highlights the importance of rig personnel understanding the systems that they are using. This was based on a real situation where a hydraulically operated pipe handling system had some contamination in the hydraulic oil. This led to frequent stoppages (due to inconsistent movement). The rig crew did not understand the problem and their attempt to troubleshoot the root cause of the failure was incorrect. They opened the machine's electrical panel and pushed the "reset" button in the hopes that would restart the system and potential solve the issue. The "reset" button, however, also served as the calibration reset. Repeat, incorrect use of the "reset" button resulted in a total failure of the pipe handling system. The end result was a need for support from an OEM technician to resolve the issue. Due to the time involved with securing the OEM technician, the consequence of the failure was escalated from a few hours of downtime (to flush out the hydraulic system and clean it) to four or five days of downtime (to send the appropriate OEM technician and troubleshoot the system). The serves as an example of reducing the consequence of failure with the correct training and system knowledge.

3.3 Anti-Collision System Fault Leading to Drawworks Stoppage

This final example demonstrates the importance of thorough system integration assessments and the complexity of inter-relationships between systems on automated rigs. In this example, while a rig was tripping out of the hole (the drawworks hoisting drill-pipe at high speed and low load), a faulty sensor in a different system (in-line compensator, which was not being used) triggered an anti-collision system shutdown. The led to the emergency brakes on the drawworks engaging very quickly, which led to a very fast stoppage of the drawworks drum at high speed, leading to the continued upward movement of the travelling block. The led the wire rope (fast-line) to move from its grooves on the crown-block (also referred to as “bird’s nest”). This was a very critical failure because it had the potential to part the wire rope which could have resulted in injuries or fatalities, and/or significant equipment damage. A detailed risk assessment would have identified the critical shutdown signals from other systems and would have identified that the commands from these signals should be ignored while these systems are not in use.

4 Conclusion

We have attempted to demonstrate the importance and need for a well-planned risk assessment process during the design and construction of deep-water rigs. This is especially true for rigs that are highly automated with complex systems. The benefits include significant risk reduction, better system integration, and detailed training and understanding of these systems by the rig crews.