Risk Assessment for Life Cycle Management and Failure Reporting Systems Task 2 Draft Report: LCM Systems

Submitted to
The Bureau of Safety and Environmental Enforcement (BSEE)

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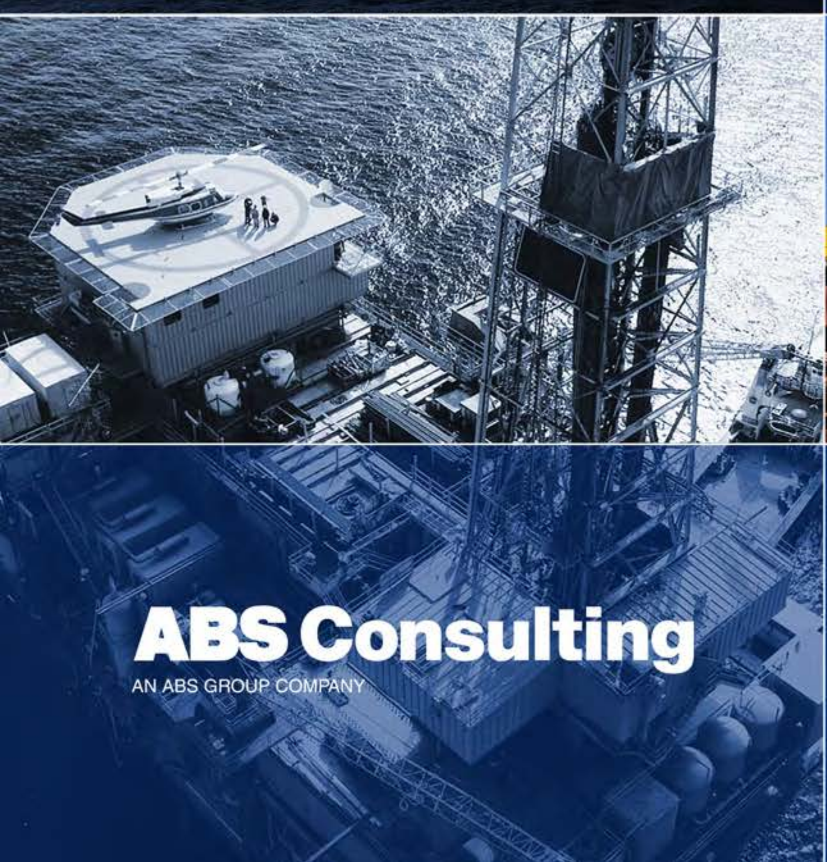

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Executive Summary

ABS Consulting prepared this report for the Bureau of Safety and Environmental Enforcement (BSEE) to provide support in development of a risk management system. The goal of this Task Report is to enhance efficiency, effectiveness, and risk reductions in the regulated Oil and Gas industry.

Based on the findings from the Task 1 Report, ABS Consulting conducted a further analysis of selected agencies and industry organizations. Each agency and organization was reviewed for further programmatic elements, best practices, the role of the regulated industry, statutory regulatory elements, effectiveness, data, and the onus of liability.

In this Task 2 Report, we conducted a review of the following agencies and organizations:

- Domestic Agencies:
  - Department of Homeland Security: United States Coast Guard
  - Department of Transportation: Federal Highway Administration
- International Agencies:
  - New Zealand Department of Labor
  - Norway Petroleum Safety Authority
  - United Kingdom Health and Safety Executive
- Industry Organizations:
  - American Waterways Operators
  - International Organization for Standards
  - American Petroleum Institute
  - International Association of Drilling Contractors
  - Industry Representative Company

Based on the review of these agencies and organizations, ABS Consulting compiled findings for what a Life Cycle Management (LCM) system can contain and what the main components that make a functional LCM system. Several of the LCM systems in place are often paired with other safety and management systems like the Safety and Environmental Management System or a Failure Reporting System, or as part of an integrated, custom-built software solution unique to the company. For example, programs like the American Waterways Operators' Responsible Carrier Program incorporate maintenance and aspects of LCM into their program, but as one component.

One of the main findings of the review is the importance of definitions. Having clear, understandable definitions that can uniformly apply across the industry will aid in the collection and aggregation of data that can be used for risk analysis. If BSEE implements regulations mandating an LCM system, BSEE would need to set clear and understandable definitions and guidelines, even if incorporating an industry standard or best practice. This will be further addressed in the Task 4 Report.

A main issue raised by industry representatives and evidenced throughout many of the agencies is the data collected. An LCM system may not need much data submitted to BSEE for review, but should instead be used by industry to identify trends in manufacturing issues or process improvements. Since maintenance data can be a massive data load, this may pose as a significant time and resource requirement, particularly in starting up a new LCM system.

Liability of data is a key issue as well. BSEE would need to strike a balance between sanitizing the data collected enough to protect and preserve the industry confidential data, but provide enough detail that trends and analysis can be conducted. BSEE would also need to be able to turn over data for analysis in a timely manner, particularly in an industry that can be fast-moving with ever-changing technologies.

The usability of the data, as well as the information gathered in this report, is dependent upon the regulatory structure that BSEE would choose to implement an LCM system. Many offshore petrochemical industry participants are currently engaged in some aspects of LCM and have robust systems in place. BSEE can implement regulations within a spectrum of approaches, from "prescriptive" regulations, characterized by command and control regulations, heavy inspection schedules and onerous reporting requirements for industry, to a regulatory approach with industry-led regulations (Figure 1). The industry-led approach can involve simply the incorporation of industry standards systems or be based on industry involvement and consensus standards. While this can allow industry more flexibility in defining the compliant system that would meet both their operational needs and the safety and data needs of the Government, liability might fall on BSEE, as the regulator-led approach may result in compartmentalized or fragmented systems which may not produce usable, industry-wide data. A "hybrid" LCM approach would be a blend of both prescriptive and industry involved LCM models.

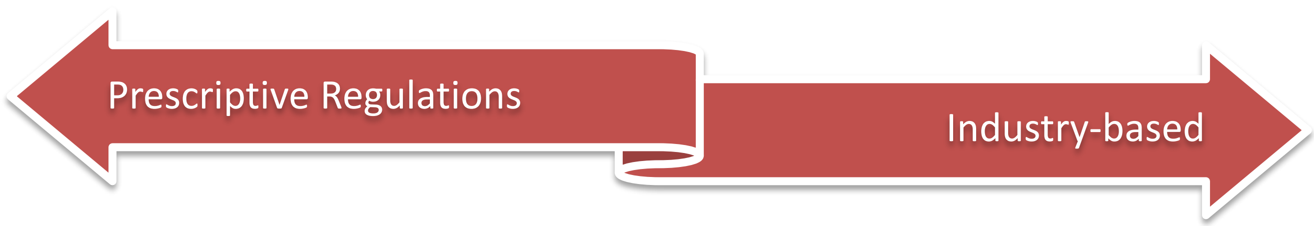

Figure 1: Regulatory Spectrum

Feasibility is a key consideration in developing recommendations that may actually lead to successful implementation. A regulatory framework that meets the needs of the government while staying flexible enough for the industry can be difficult to identify and implement; however, this approach may ease implementation difficulties and boost industry acceptance. BSEE's aim should be to develop a regulatory regime that is robust enough to ensure the safety of employees and the environment while being flexible enough to allow industry to continue with their best practices. In this way, BSEE can avoid creating redundant or onerous resource and financial burdens on industry.

Incorporation of industry standards like American Petroleum Institute Specifications for Quality Programs Q1 and Q2 will provide a basis for the development of a system, and, with additional regulatory guidelines, industry can develop their programs within that framework. BSEE can then develop further guidelines and structure to ensure consistency across the industry. By incorporating these standards by reference, it is likely that BSEE can improve regulatory acceptance as a first step. This discussion will be further addressed in the Task 5 Report.

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Table of Contents

List of Figures

List of Tables

List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AASHTOWare	American Association of State Highway and Transportation Officials Ware
ABS	American Bureau of Shipping
ACMS	Asset Computerized Maintenance System
AIAA	American Institute of Aeronautics and Astronautics
AIM	Inventory and Monitoring Strategy –or– Asset Integrity Management
ALE	Ageing and Life Extension
ANSI	American National Standards Institute
AOC	Acknowledgement of Compliance
API	American Petroleum Institute
ASD	Ministry of Labor and Social Affairs
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
AWO	American Waterways Operators
BIFA	Buses in Fatal Accidents
BOP	Blowout Preventer
BPA	Blanket Purchase Agreement
BSEE	Bureau of Safety and Environmental Enforcement
BMS	Bridge Management System
CAPA	Corrective and Preventive Action
CBI	Confidential Business Information
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CGBI	Coast Guard Business Intelligence
CG-ENG	USCG Office of Design and Engineering Standards
CG-INV	USCG Office of Investigations and Casualty Analysis
CGTO	Coast Guard Technical Order
CRR	Contract Research Report
DEA	Danish Energy Agency
DHS	Department of Homeland Security
DOT	Department of Transportation
EIA	Electronics Industry Alliance
EPA	Environmental Protection Agency
EPLC	Enterprise Performance Life Cycle
FAA	Federal Aviation Administration
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMECA	Failure Modes, Effects and Criticality Analysis

FRACAS	Failure Reporting, Analysis, and Corrective Action System
FSCAP	Flight Safety Critical Aircraft Part
GTL	Gas to Liquid
HIRA	Hazard Identification and Risk Analysis
HPMS	Highway Performance Monitoring System
HSE	Health and Safety Executive (Britain)
HSIP	Highway Safety Improvement Program
IADC	International Association of Drilling Contractors
IAEA	International Atomic Energy Agency
IBC	International Building Code
IEEE	Institute of Electrical and Electronic Engineers
IMHH	Industry Mutual Hold Harmless deed
IMO	International Maritime Organization
IRC	International Residential Code
IRI	International Roughness Index
IRS	Incident Reporting System
ISO	International Organization for Standardization
ISP	Incidents Statistics Program
ISTEA	Intermodal Surface Transportation Efficiency Act
KP3	Key Program 3
KP4	Key Program 4
KSA	Knowledge, Skills and Abilities
LCA	Life Cycle Assessment
LCM	Life Cycle Management
LER	Licensee Event Report
LIMS	Logistics Information Management System
MAP-21	Moving Ahead for Progress in the 21st Century Act
MBIE	Ministry of Business, Innovation and Employment
MISLE	Marine Information System for Safety and Law Enforcement
MOC	Management of Change
MODU	Mobile Offshore Drilling Units
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NOPSA	National Offshore Safety Authority
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NRC	Nuclear Regulatory Commission
NTSB	National Transportation Safety Board
NVIC	Navigation and Vessel Inspection Circulars
O&G	Oil and Gas
OCS	Outer Continental Shelf
OEM	Original Equipment Manufacturer

OSHAS	Occupational Safety and Health Administration Services
OWL	Web Ontology Language
PAS	Publicly Available Specification
PDCA	Plan-Do-Check-Act
PHMSA	Pipeline Hazardous Materials Administration
PMS	Pavement Management System
PSA	Petroleum Safety Authority (Norway)
PSSR	Pressure Systems Safety Regulation
RBI	Risk-Based Inspection
RCM	Reliability Centered Maintenance
RCP	Responsible Carrier Program
RNNP	Trends in Risk Level Norwegian Petroleum Activity (Norwegian)
RP	Recommended Practice
SAE	Society of Automotive Engineers
SAICM	Strategic Approach to International Chemicals Management
SELC	Systems Engineering Life Cycle
SEMATEC	Semiconductor Manufacturing Technology Consortium
SEMS	Safety and Environmental Management Systems
SHSP	Strategic Highway Safety Plan
SME	Subject Matter Expert
SMS	Safety Management System
SSI	Sensitive Security Information
TIA	Telecommunications Industry Association
TIFA	Trucks in Fatal Accidents
TS	Technical Specification
TVIB	Towing Vessel Inspection Bureau
U.K.	United Kingdom
UKCS	United Kingdom Continental Shelf
U.S.	United States
USCG	United States Coast Guard

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1. Objectives and Purpose

As a continuation from Task 1, this task further analyzes previously identified Life Cycle Management (LCM) systems. In keeping with the Bureau of Safety and Environmental Enforcement's (BSEE) mission, this report provides a further review and breakdown of identified LCM systems from other regulators and from industry.

LCM systems provide a way for the Oil and Gas (O&G) industry to monitor the functionality and performance condition of any piece of equipment, component, or system. In order to support BSEE in developing an effective regulatory program, this project will validate the knowledge and findings from the Task 1 Report: Agency Review. Specifically, American Bureau of Shipping (ABS) Consulting will assist BSEE in creating a regulatory program based on risk management for Outer Continental Shelf (OCS) O&G operations.

Additionally, we have identified the key elements of an LCM system. These elements include the policies and regulations enacted, the activities of responsible parties, and the different approaches used to implement or regulate an LCM system. Following the review of the selected agencies, ABS Consulting compiled several findings that BSEE can adopt to strengthen its regulatory-related guidance document processes. This, in turn, will enable greater effectiveness and flexibility for BSEE to regulate a complex and fast-paced industry.

2. Introduction

LCM systems are an integral part of a successful organization. These systems are vital to ensure that costs are reduced while simultaneously maintaining an ever safer operating environment. This report describes the results of inquiries and analyses in support of contract E14PB00045, Risk Assessment for Life Cycle Management and Failure Reporting Systems. It describes the results of inquiries and analyses in support of Task 2 of the subject Call Order. The purpose is to identify LCM concepts for critical equipment used in OCS O&G operations and recommend changes to 30 Code of Federal Regulations (CFR) 250. In keeping with BSEE's mission, this Task 2 report provides a deeper review of the LCM systems and recommends improvements that BSEE can implement.

The report provides an analysis of the selected domestic agencies, international agencies, and industry representatives. ABS Consulting aimed to capture features that may be appropriate for BSEE to consider in developing its requirements for an LCM system. The information gathered during this research will be used to create an initial definition of critical systems, equipment, and components and to develop recommendations for possible changes to BSEE's regulations and procedures.

Several of the key findings and theories identified in Task 1 were further investigated and elaborated upon. LCM systems were analyzed for the policies, regulations, industry standards, guidelines or official communications they incorporated. This part of the analysis will provide the structure for how other regulators and industry representatives have developed and implemented LCM systems.

3. Approach

Our Task 2 efforts built upon our results from Task 1 and further analyzed previously identified LCM systems. ABS Consulting approached Tasks 2 and 3 simultaneously. Task 2 focused on LCM systems, while Task 3 addressed Failure Reporting Systems and, therefore, is reported on separately. For Task 2, we analyzed the LCM systems of agencies and organizations identified in Task 1 as potentially applicable to BSEE. This was performed in order to discern the validity and functionality of those LCM systems. ABS Consulting created a template to ensure that each agency or organization was analyzed in a comparable manner[1].

ABS Consulting conducted outreach to the selected agencies and coordinated with our international offices to obtain information for international regulators. ABS Consulting used a standard template to review and collect consistent data for each identified program and, consequently, was able to gather uniform information.

Once the information for each agency was collected, ABS Consulting reviewed data across the various LCM systems to identify key commonalities, components, trends, and viability, in addition to each system's overall applicability to BSEE. Given the list of selected agencies and their associated industries, it is possible that some programs might not be applicable to the OCS O&G industry. The LCM systems, therefore, merited further scrutiny to help ensure potential functionality, viability, and acceptance by the industry. These elements are essential to understanding how to best implement and manage an LCM system.

ABS Consulting analyzed these findings further to provide feedback and options for progress forward. As a result of our Task 2 efforts, ABS Consulting is providing preliminary recommendations for LCM systems that, along with our Task 3 findings on Failure Reporting Systems, will inform Tasks 4 and 5 of the Call Order.

4. Agency/Organizational Review

The following section is an in depth review of organizations initially evaluated in the Task 1 report and subsequently selected by BSEE for further review. This section is separated into three sections: Domestic Federal Agencies, International Regulators and Industry. Each organization reviewed in this section has been thoroughly researched to identify the elements listed in the Task 2 description statement of work for this project. The following information describes the findings of this research.

[1] Templates are included in Appendix A

4.1 Domestic Federal Agencies

The information in this sub-section describes the data collected for the following organizations: the Department of Transportation (DOT), the Federal Highway Administration (FHWA); and the Department of Homeland Security (DHS) United States Coast Guard (USCG).

4.1.1 Department of Homeland Security – United States Coast Guard

The USCG's mission is to ensure the safety and security of people on vessels, to protect the environment from the impacts of maritime operations, and to facilitate the flow of commerce on U.S. waterways. As a regulatory agency, the USCG has been involved in inspecting vessels to varying degrees since 1838. Over the years, new legislation has been enacted to provide the USCG with additional authorities, usually in response to marine disasters that have occurred.

In Section 2 of the Blanket Purchase Agreement (BPA) Call Order No. E14PB00045, BSEE offered a description of an LCM system "as inclusive of the following as related to a piece of equipment; design, fabrication, installation, repair and maintenance, failure reporting/analysis, design modification/ refurbishment/re-specification, and operation" (BPA Call Order No. E14PB00045, 2014). Using the BSEE description of an LCM system, the following discussion will examine the USCG's use of LCM systems from two perspectives. The first perspective is the application of LCM systems external to the USCG; the second perspective is internal to the USCG's application of LCM systems.

4.1.1.1 History

Prior to World War II, few standards and specifications were defined for materials being used to build or equip U.S. flag vessels; subsequently, products lacked uniformity. The USCG had no way to distinguish acceptable materials or equipment from substandard ones. As a result of this lack of quality assurance, there were numerous catastrophic failures that led to the loss of life. In 1945, the USCG promulgated the regulations in 46 CFR Subchapter Q, Parts 160-164. These regulations consolidated the standards for equipment and materials and ensured that the USCG developed minimum standards for certain materials and equipment.

Given BSEE's definition of an LCM system, the USCG's enforcement of Title 46 of the CFRs can be inferred as a de facto imposition of an LCM system that is already applicable to the OCS. Specifically, Subchapters F, I-A, J, Q and W address the "*maintenance, failure reporting/analysis, design modification/refurbishment/re-specification, and operation*" of critical equipment (BPA Call Order No. E14PB00045, 2014). Though the term LCM is never used in these regulations, it is clear that the intent of these regulations is to control critical components and utilize reporting to "*promote safety, protect the environment, and conserve resources offshore through vigorous regulatory oversight and enforcement*" (BPA Call Order No. E14PB00045, 2014). Parts of these regulations establish or incorporate by reference standards for the design, materials, installation, and modification of critical equipment. Other parts clearly define standards for maintenance, refurbishment, and recertification of critical equipment.

The regulations in Title 46 CFR are far from a model of proactive risk assessment-based principles. These regulations, for the most part, are the accumulation of years of experience, typically the result of industry's failure to promote safety or protect the environment. Secondly, because the USCG's primary responsibility is for the hull structure, electrical system safety, and lifesaving and firefighting systems, many components considered critical by BSEE may not fall under the scope of Title 46 CFR. However, if BSEE expanded their interpretation of an LCM and explored 46 CFR in this broader context, there may be lessons and opportunities to contribute to their effort.

In addition to the regulatory regime that functions as an LCM, it should also be recognized that the USCG has its own internal LCM system. The USCG has no single methodology or policy that speaks to the agency-wide application of an LCM system. Instead, the USCG uses a hierarchy of agency-wide policies that address the various aspects of an LCM system for assets it owns and operates. The USCG developed most of these policies in the last ten to twenty years. Though these policies do not specifically use the term LCM in most cases, they address the same processes associated with LCM. The fragmentation of these policies would make it difficult for BSEE to neatly extract models or examples that could be applied to the OCS. However, there are components of these policies that could help BSEE define the structure of an LCM system.

4.1.1.2 Information, Policies, and Procedures

Standards from trade groups or trade associations are fully integrated into the regulatory structure of 46 CFR. In particular, many of the material standards in 46 CFR Subchapters F, J, and Q incorporate by reference the criteria of many well recognized standards organization such as: American Petroleum Institute (API), ABS, American Society for Testing and Materials (ASTM), Institute of Electrical and Electronic Engineers (IEEE), International Standard for Organization (ISO), National Electrical Manufacturers Association (NEMA), and National Fire Protection Association (NFPA).

The USCG's internal policies and programs do not come directly from industry, trade groups, or trade associations, but many polices or guidelines are incorporated by reference to recognized standards organization such as: Air Transport Association (ATA), American Welding Society, Manufacturers Standardization Society of the Valve and Fittings Industry, Compressed Gas Association (CGA), Fluid Sealing Association, Society of Automotive Engineers (SAE), the Society for Protective Coatings, Boating Industry of America, Telecommunications Industry Association (TIA), Electronics Industry Alliance (EIA), International Building Code (IBC), the National Electrical Code (NEC), and International Residential Code (IRC).

The USCG has, broadly speaking, two levels of policy related to LCM. Higher level policies provide agency-wide strategic LCM guidance related to the acquisition, operation, maintenance, and disposal of major assets. Lower levels of policies are structured to address the LCM processes based on major asset categories (i.e., facilities, aircraft, vessels, electronics, etc).

The primary policy related to the acquisition phase of LCM is *Commandant Instruction Manual 5000.10C, Major Systems Acquisition Manual*. Direct applicability of this policy to BSEE's desired examination stems mostly from a comparative analysis of terms and definitions. Specifically, there are two key components of this policy that provide a cradle-to-grave philosophy of LCM that are informative. The first is the Systems Engineering Life Cycle (SELC) framework. The USCG defines SELC as the "…execution, and management of an interdisciplinary set of tasks and formal reviews required to plan, define, design, develop, implement, operate and dispose of systems." The second is the Life Cycle Cost Estimate process, which provides the foundation for USCG business decisions concerning project affordability (Commandant Instruction Manual 5000.10C Major Systems Aquisition Manual, 2013). Project managers are required to obtain guidance and best practices from the GAO Cost Estimate and Assessment Guide, GAO-09-3SP regarding specifics on developing a Life Cycle Cost Estimate (U.S. Coast Guard, 2015).

Once a major acquisition has been completed and the major assets are operational, the controlling USCG policy regarding LCM is *Commandant Instruction M4500.5D., U.S. Coast Guard Personal Property Management Manual*. This policy states that maintenance programs for USCG-owned aircraft must comply with Title 41 CFR, Part 102-33 (Commandant Instruction M4500.5D., Personal Property Management Manual, 2013). Additionally, the USCG defines the term "Life Cycle" in this policy as "*Taken together, the steps or phases experienced by an item of property from acquisition through disposition.*" The policy also describes the management of personal property management (i.e., LCM), as "the control over acquisition, management, utilization, reutilization, excess, accounting, and disposal of property."

This regulatory reference is important because 41 CFR, Part 102-33.170(d) mandates, "Procedures for recording and tracking maintenance actions; inspections; and the flight hours, cycles, and calendar times for life-limited parts and FSCAP [Flight Safety Critical Aircraft Part]." The FSCAP concept has direct applicability to BSEE's inquiry. 41 CFR Part 102-33.20 defines FSCAP as, "…any military aircraft part, assembly, or installation containing a critical characteristic whose failure, malfunction, or absence could cause a catastrophic failure resulting in loss or serious damage to the aircraft or an uncommanded engine shutdown resulting in an unsafe condition." According to 41 CRF Part 102-33.5 and 102.33.15, the concept of FSCAP in this instance is related to Public Contracts and Property Management and applies to "all federally funded aviation activities of executive agencies of the U.S. Government" but does not supercede any regulations related to Federal Aviation Regulations. Therfore, FSCAP is not directly applicable to and LCM system; rather the definition of a "Critical Aircraft Part" can help shape BSEE's definitions.

In the hierarchy of policies, the next level becomes asset specific and addresses the unique requirements of LCM for each asset category. The following discussion will focus on four policy manuals that provide LCM guidance for major asset categories: aeronautical, naval, civil, and electronic engineering.

Commandant Instruction M13020.1, Aeronautical Engineering Maintenance Manual promulgates policy related to USCG aircraft. The policy makes it clear that these standards are met by performing maintenance, which includes inspection, repair, overhaul, modification, preservation, testing, and condition or performance analysis. The USCG uses a Reliability Centered Maintenance (RCM) philosophy for its aircraft. This policy does not define RCM, but references a detailed discussion of the subject in the *RCM Process Guide, Coast Guard Technical Order (CGTO) PG-85-00-30,* which states:

> *The RCM Program is an organized procedure designed to monitor the reliability of aircraft components by utilizing historical maintenance data and statistical methods. Experience has shown that this technique is an accurate method of evaluating the reliability of aircraft systems and components. The program monitors the performance of aircraft components continuously and brings problems and deteriorating trends to the attention of Coast Guard management. The program determines whether preventive action is needed if the inherent reliability of components is not realized.*

The *RCM Process Guide, CGTO PG-85-00-30* could be useful to BSEE, as it outlines a maintenance philosophy and concepts that BSEE could apply to the offshore industry. There is also a decision logic-model in the guide that highlights how the crew should address a functional failure shown in Figure 2 below. From this model we can see that functional failures are initially divided into what is evident and what is hidden. Then, the decision tree moves to whether the failure poses a safety, mission, or non-mission (economic) effect. No matter the particular effect, the steps addressing each failure are generally the same:

- Lubrication & servicing;
- Operational check/visual inspection;
- Inspection/functional check;
- Restoration;
- Discard; or
- Combination of tasks.

The applicability of each of these steps is dependent on the failure not being resolved through a previous task, with the first being lubrication & servicing. The effectiveness of each task is evaluated for the safety and mission effects. Accordingly, each should be completed so the risk of failure is reduced to an acceptable level. For the non-mission (economic) effects, each task should be completed so that it is cost effective, specifically in that the cost of the task is less than the cost associated with the failures prevented (United States Coast Guard, 2006).

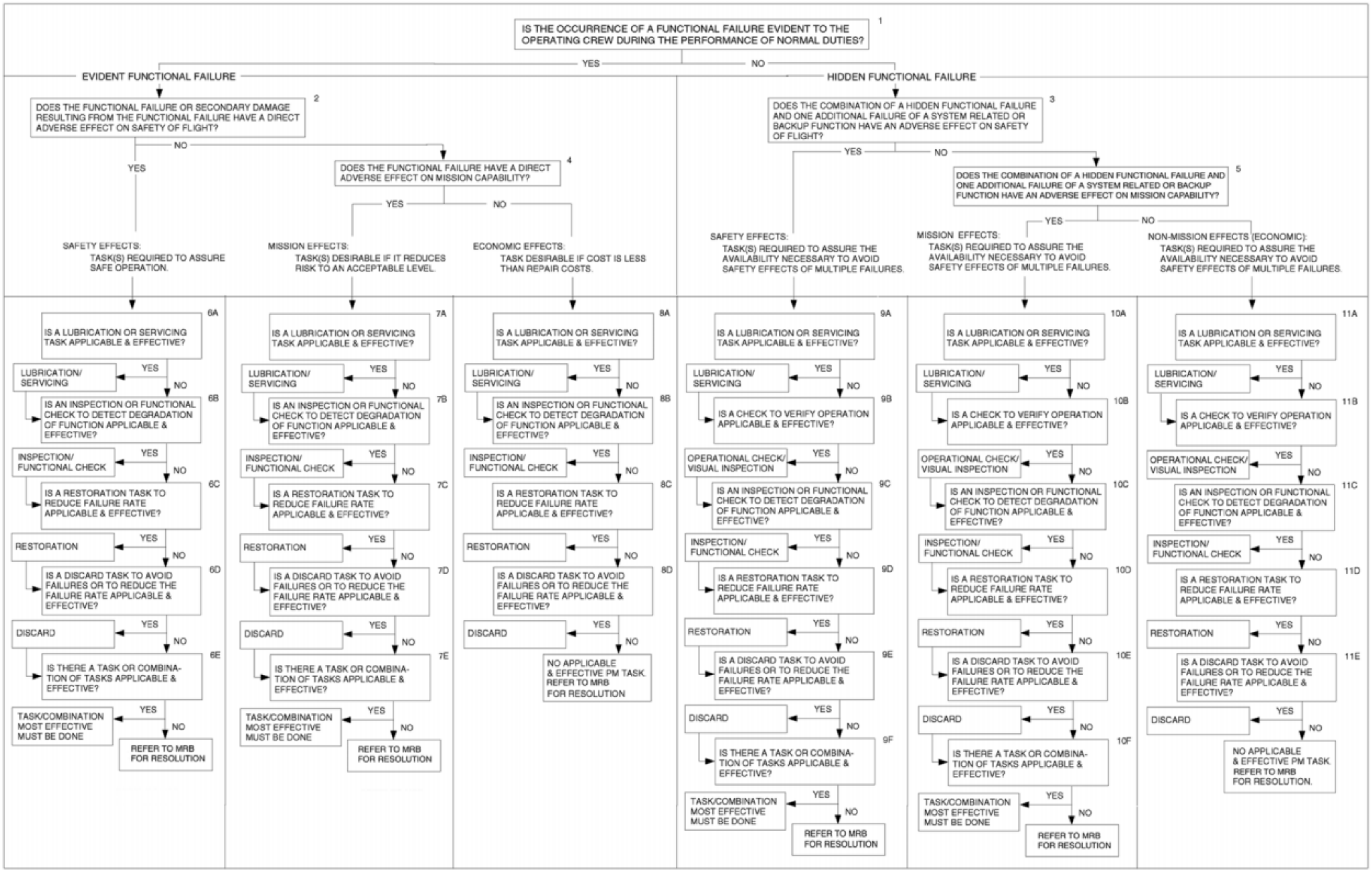

Figure 2: RCM Logic Model (United States Coast Guard, 2006)

The model provides a systematic approach for evaluating aircraft systems and components to determine preventive maintenance requirements. The guide also has an interesting discussion of trend analysis and corrective action; trend analysis being considered a cornerstone of a Reliability-Centered Maintenance program in that it helps track removal rates of systems and components and helps model problem areas in order to initiate corrective action (Reliability Centered Maintenance (RCM) Process Guide, CGTO PG-85-00-30 , 2006). Another major component of *Commandant Instruction M13020.1* is the introduction of FSCAP. As previously discussed, the USCG is required to have procedures to identify and control flight safety critical aircraft parts throughout the material's life cycle.

The USCG currently uses an Asset Computerized Maintenance System (ACMS) software program that tracks FSCAP to individual maintenance tasks by discrete barcode numbers. The barcode numbers link FSCAP designated parts to specific maintenance tasks. However, as a matter of redundancy, a user can input a component's serial number and Component End Item Number in case a barcode is not applicable or has fallen off. This program will probably not have any direct applicability to the offshore industry, but it is a tangible example of the management of "critical equipment." *Commandant Instruction M13020.1* does not directly define ACMS, but references the *ACMS Users Process Guide, CGTO PG-85-00-10*. The guide provides a detailed description of the forms, reports, and procedures associated with ACMS (Commandant Instruction M13020.1, Aeronautical Engineering Maintenance Manual, 2011). It is important to note that as of December 2014, the USCG announced it has implemented a Logistics Information Management System (LIMS) as the primary maintenance software for the HC-144A Ocean Sentry aircraft fleet. If the implementation of the system goes well with the HC-144A Ocean Sentry aircraft fleet, the USCG has the option to transition to the LIMS for all of its aircraft and some of its vessels by the end of 2018.

Finally, there is the *Commandant Instruction M10550.25, Electronics Manual*. This manual addresses LCM more directly and extensively than any other USCG policy discussed to this point. The manual describes five stages of the life cycle of electronic equipment -- acquisition and procurement, installation, equipment maintenance, equipment engineering changes, and equipment disposition. The manual also has two chapters devoted to life cycle; one chapter addresses LCM for general use electronic equipment and the other addresses LCM for electronic test equipment. In addition to the two chapters devoted to life cycle, the manual has numerous chapters devoted to installation and maintenance processes. At 755 pages, the *Commandant Instruction M10550.25, Electronics Manual* is comprehensive in its scope and detail as it relates to the principles of LCM (Commandant Instruction M10550.25, Electronics Manual, 2007). Unfortunately, it is so detailed and so specific to USCG-related systems that it would be difficult to apply the policy to any other system or agency because the components and systems mentioned in this manual are very specific, such as the broadcasting frequencies of radios used by the USCG. This is done intentionally, as the target audiences of this manual are electronics technicians tasked to repair and maintain the components and systems. Therefore, while the manual is descriptive in the methods of maintaining the systems and components, it is completely specific to the USCG.

4.1.1.3 Elements, Best Practices, Lessons Learned

In *Commandant Instruction Manual 5000.10C, Major Systems Acquisition Manual,* the USCG describes its LCM policy basis as a cycle of requirements, which are depicted in Figure 3. The effectiveness of each element within the requirements life cycle is dependent on its predecessor. Each step in the process builds upon the proceeding step.

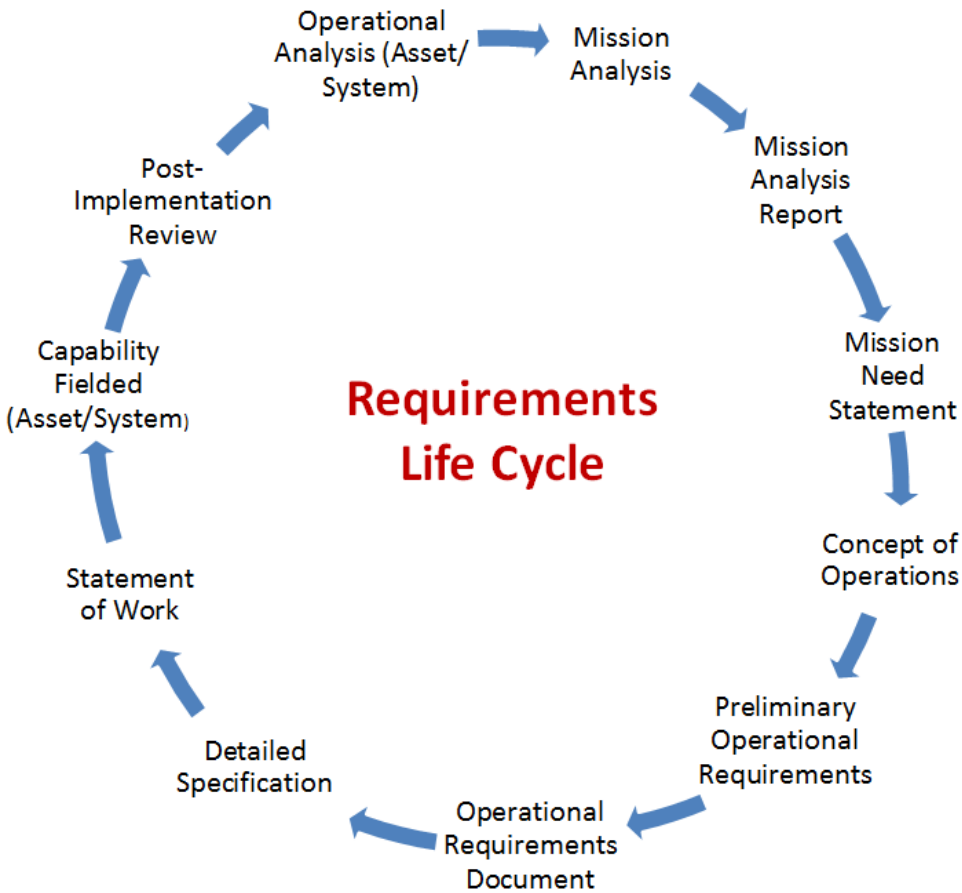

Figure 3: Major Systems Acquisition Cycle

In support of the requirements life cycle, the policy establishes a Systems Engineering Life Cycle (SELC) framework. The SELC is a one of the key processes for USCG acquisition programs and their related projects. The SELC guides the definition, execution, and management of an interdisciplinary set of tasks required to plan, define, design, develop, implement, operate, and dispose of systems. The eight stages of the SELC model, with an explanation of each stage are presented in Figure 4.

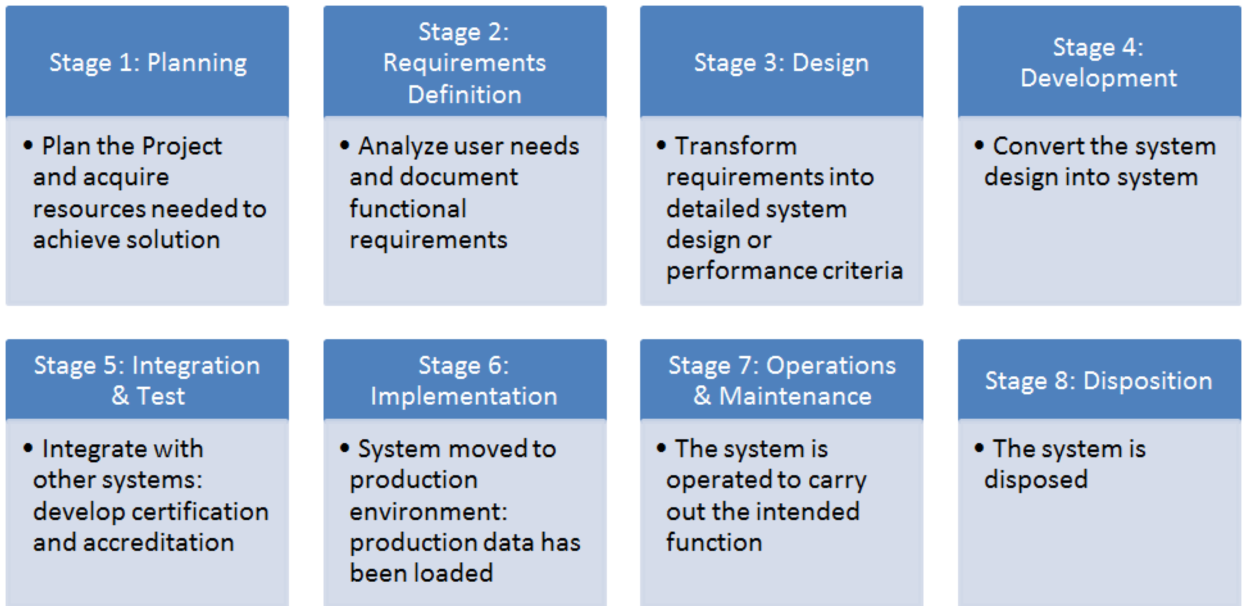

Figure 4: Stages of the SELC Model

The USCG uses industry standards and specifications in the regulatory structures of 46 CFR which highlights how government agencies can implement existing industry standards and specifications in development of guidelines. This helps reduce duplication of effort while providing an acceptable end result. The following list is not all inclusive, but representative of standards recently reapproved for incorporation:

- American National Standards Institute (ANSI)/ISA 12.12.01–2012, Nonincendive Electrical Equipment for Use in Class I and II, Division 2 and Class III, Divisions 1 and 2 Hazardous (Classified) Locations
- ANSI/ISA 60079–18—Electrical Apparatus for Use in Class I, Zone 1 Hazardous (Classified) Locations: Type of Protection—Encapsulation ''m'', 2012 (''ANSI/ISA 60079–18'')
- ANSI/UL 674—Electric Motors and Generators for Use in Division 1 Hazardous Locations (Classified) Locations, 5th Edition (''ANSI/UL 674'')
- ANSI/UL 823—Electric Heaters for Use in Hazardous (Classified) Locations, 9th Edition (''ANSI/UL
- 823'')
- ANSI/UL 844—Electric Lighting Fixtures for Use in Hazardous (Classified) Locations, 13th Edition
- (''ANSI/UL 844'')
- ANSI/UL 913—Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II and III, Division 1, Hazardous Locations, 7th Edition (''ANSI/UL 913'')
- ANSI/UL 1203—Explosion-proof and Dust-ignition Proof Electrical Equipment for use in Hazardous (Classified) Locations, 4th Edition (''ANSI/UL 1203'')
- ANSI/UL 2225—Cables and Cable Fittings for use in Hazardous (Classified) Locations, 3rd Edition (''ANSI/UL 2225'')

- ASTM F2876–10—Standard Practice for Thermal Rating and Installation of Internal Combustion Engine Packages for use in Hazardous Locations in Marine Applications (‘‘ASTM F2876– 10’’)
- CSA C22.2 No. 0–M91—General Requirements—Canadian Electrical Code, Part II, July 1991, Reaffirmed2006 (‘‘CSA C22.2 No. 0–M91’’)
- CSA C22.2 No. 30–M1986—Explosion-Proof Enclosures for Use in Class I Hazardous Locations, November 1988, Reaffirmed 2007 (‘‘CSA C22.2 No. 30–M1986’’)
- CSA C22.2 No. 157–92—Intrinsically Safe and Non-incendive Equipment for Use in Hazardous Locations, June 2003, Reaffirmed 2006 (‘‘CSA C22.2 No. 157–92’’)
- CSA C22.2 No. 213–M1987—Nonincendive Electrical Equipment for Use in Class I, Division 2 Hazardous Locations, March 1987, Reaffirmed 2008 (‘‘CSA C22.2 No. 213–M1987’’)
- Class Number 3600—Approval Standard for Electric Equipment for use in Hazardous (Classified) Locations General Requirements, 1998 (‘‘FM Approvals Class Number 3600’’)
- Class Number 3610—Approval Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations, 2010 (‘‘FM Approvals Class Number 3610’’)
- Class Number 3611—Approval Standard for Nonincendive Electrical Equipment for Use in Class I and II, Division 2, and Class III, Divisions 1 and 2, Hazardous (Classified) Locations, 2004 (‘‘FM Approvals Class Number 3611’’)
- Class Number 3615—Approval Standard for Explosion proof Electrical Equipment General Requirements, 2006 (‘‘FM Approvals Class Number 3615’’)
- Class Number 3620—Approval Standard for Purged and Pressurized Electrical Equipment for Hazardous (Classified) Locations, 2000 (‘‘FM Approvals Class Number 3620’’)
- IEC 60079–1—Explosive Atmospheres—Part 1: Equipment Protection by Flameproof Enclosures ‘‘d’’, Sixth Edition, 2007 (‘‘IEC 60079– 1’’)
- IEC 60079–2—Explosive Atmospheres—Part 2: Equipment Protection by Pressurized Enclosures ‘‘p’’, Fifth Edition, 2007 (‘‘IEC 60079– 2’’)
- IEC 60079–5—Explosive Atmospheres—Part 5: Equipment Protection by Powder Filling ‘‘q’’, Third Edition, 2007 (‘‘IEC 60079–5’’)
- IEC 60079–6—Explosive Atmospheres—Part 6: Equipment Protection by Oil Immersion ‘‘o’’, Third Edition, 2007 (‘‘IEC 60079–6’’)
- IEC 60079–7—Explosive Atmospheres—Part 7: Equipment Protection by Increased Safety ‘‘e’’, Fourth Edition, 2006 (‘‘IEC 60079–7’’)
- IEC 60079–11—Explosive Atmospheres—Part 11: Equipment Protection by Intrinsic Safety ‘‘i’’, Sixth Edition, 2011 (‘‘IEC 60079–11’’)
- IEC 60079–13—Explosive atmospheres—Part 13: Equipment protection by pressurized room ‘‘p’’, Edition 1.0, 2010 (‘‘IEC 60079–13’’)
- IEC 60079–15—Explosive Atmospheres—Part 15: Equipment Protection by type of protection ‘‘n’’, Edition 4.0, 2010 (‘‘IEC 60079–15’’)

- IEC 60079–18—Explosive Atmospheres—Part 18: Equipment Protection by Encapsulation ''m'', Edition 3.0, 2009 (''IEC 60079–18'')
- IEC 60079–25—Explosive Atmospheres—Part 25: Intrinsically safe electrical systems, Edition 2.0, 2010 (''IEC 60079–25'')
- IEC 60092–502—Electrical Installation in Ships—Tankers— Special Features, Fifth Edition, 1999 (''IEC 60092–502'')
- IEC 61892–7, Mobile and Fixed Offshore Units—Electrical Installations—Part 7: Hazardous Areas, Second Edition, 2007 (''IEC 61892–7'')
- NEC 2011—National Electrical Code, 2011 (''NFPA 70'')
- NFPA 496—Standard for Purged and Pressurized Enclosures for Electrical Equipment, 2013 Edition (''NFPA 496'')
- UL 1604—Electrical Equipment for use in Class I and II, Division 2 and Class III Hazardous (Classified) Locations, Third Edition, (''UL 1604'')
- ASTM F722-82 (1993) F722-82 (Reapproved 2008)-Standard Specification for Welded Joints for Shipboard Piping Systems
- ASTM F1121-87 (1993) F1121-87 (Reapproved 2010)-Standard Specification for International Shore Connections for Marine Fire Applications
- ASTM A134-96 A134-96 (Reapproved 2012)-Standard Specification for Pipe, Steel, Electric-Fusion (Arc)—Welded (Sizes NPS 16 and Over)
- ASTM A179/A179M-90a (1996) A179/A179M-90a (Reapproved 2012)-Standard Specification for seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
- ASTM A203/A203M-97 A203/A203M-97 (Reapproved 2007)-Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel
- ASTM A214/A214M-96 A214/A214M-96 (Reapproved 2012)-Standard Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes
- ASTM A536-84 (1993)A536-84 (Reapproved 2009)-Standard Specification for Ductile Iron Castings
- ASTM A575-96 A575-96 (Reapproved 2007)-Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
- ASTM A576-90b (1995) A576-90b (Reapproved 2012)-Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
- ASTM D1434-82 (1988) D1434-82 (Reapproved 2009)-Standard Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting
- ASTM F682-82a F682-82a (Reapproved 2008)-Standard Specification for Wrought Carbon Steel Sleeve-Type Pipe Couplings
- ASTM F1006-86 (1992)F1006-86 (Reapproved 2008)-Standard Specification for Entrainment Separators for Use in Marine Piping Applications
- ASTM F1007-86 (1996) F1007-86 (Reapproved 2007)-Standard Specification for Pipeline Expansion Joints of the Packed Slip Type for Marine Application

- ASTM F1020-86 (1996) F1020-86 (Reapproved 2011)-Standard Specification for Line-Blind Valves for Marine Applications
- ASTM F1120-87 (1993) F1120-87 (Reapproved 2010)- Standard Specification for Circular Metallic Bellows Type Expansion Joints for Piping Applications
- ASTM F1123-87 (1993) F1123-87 (Reapproved 2010) Standard Specification for Non-Metallic Expansion Joints
- ASTM F1139-88 (1993) F1139-88 (Reapproved 2010)-Standard Specification for Steam Traps and Drains
- ASTM F1172-88 (1993) F1172-88 (Reapproved 2010)-Standard Specification for Fuel Oil Meters of the Volumetric Positive Displacement Type
- ASTM F1199-88 (1993) F1199-88 (Reapproved 2010)-Standard Specification for Cast (All Temperatures and Pressures) and Welded Pipe Line Strainers (150 psig and 150 °F Maximum)
- ASTM F1200-88 (1993) F1200-88 (Reapproved 2010-)Standard Specification for Fabricated (Welded) Pipe Line Strainers (Above 150 psig and 150 °F)
- ASTM F1201-88 (1993) F1201-88 (Reapproved 2010)-Standard Specification for Fluid Conditioner Fittings in Piping Applications Above 0 °F
- ASTM F1271-90 (1995) F1271-90 (Reapproved 2012)-Standard Specification for Spill Valves for Use in Marine Tank Liquid Overpressure Protections Applications
- ASTM F1273-91 (1997) F1273-91 (Reapproved 2007)-Standard Specification for Tank Vent Flame Arresters
- ASTM F1546/F1546 M-96 F1546/F1546M-96 (Reapproved 2012)-Standard Specification for Fire Hose Nozzles

The USCG also uses industry standards and specifications in the acquisition and maintenance of the major assets it owns and operates. These include:

- ATA
- API
- ABS Rules for Building and Classing Steel Ships
- ASTM
- American Welding Society
- IEEE
- ISO
- Manufacturers Standardization Society of the Valve and Fittings Industry
- CGA
- Fluid Sealing Association
- NEMA
- NFPA
- SAE
- The Society for Protective Coatings

- Boating Industry of America
- ANSI
- TIA
- EIA
- IBC
- NEC
- IRC

4.1.1.4 Statutory/Regulatory Elements

46 CFR viewed in the context of a LCM system contains many regulations to support the USCG goals of promoting safety and environmental protection. Table 1below contains a list of the CFR subchapters applicable to marine safety and vessel inspection and those containing regulations pertaining to lifecycle maintenance requirements.

Table 1: USCG Regulations Containing Lifecycle Management Requirements

Title 46 Code of Federal Regulations – Shipping		
Subchapter	Par	Subject
D	30-40	Tank Vessels
F	50-64	Marine Engineering
H	70-89	Passenger Vessels
I	90-106	Cargo and Miscellaneous Vessels
I-A	107-109	Mobile Offshore Drilling Units
J	110-113	Electrical Engineering
K	114-122	Small Passenger Vessels Carrying More Than 150 Passengers or with Overnight Accommodations for More Than 49 Passengers
L	125-139	Offshore Supply Vessels
N	146-149	Dangerous Cargoes
O	150-155	Certain Bulk Dangerous Cargoes
Q	159-165	Equipment, Construction and Material: Specifications and Approval
R	166-169	Nautical Schools
S	170-174	Subdivision and Stability
T	175-187	Small Passenger Vessels
U	188-196	Oceanographic Research Vessels
V	197-198	Marine Occupational Safety and Health Standards
W	199	Lifesaving Appliances and Arrangements

In addition to these regulations, numerous guidelines exist in Navigation and Vessel Inspection Circulars (NVICs), along with procedures in divisional policy letters that inform the process. To better understand how the regulations in 46 CFR function as a LCM system, it is instructive to examine Subchapter Q. This Subchapter demonstrates how the USCG implements regulatory structures that control the "maintenance, failure reporting/analysis, design modification/refurbishment/re-specification, and operation" of critical pieces of equipment.

Though the term “critical equipment” is never used in these regulations, it would be logical to assume these systems were deemed critical enough that they required a specific regulatory regime to enforce minimum requirements. 46 CFR Subchapter Q allows the USCG to control the design, construction, and installation of these systems to ensure manufacturers maintain the minimum standard of uniformity and quality required by the regulations. The USCG maintains this control through specific oversight actions. It conducts plan reviews for equipment of new, unusual, or potentially hazardous design.

The USCG has also established a system of “type approvals” for categories of critical equipment that require USCG review and approval. In order for a piece of equipment to receive Type Approval it must comply with the requirements within the regulations, successfully complete specific tests, and be enrolled in a quality control or follow up program. While there is no charge for the USCG issuing a certificate of approval, the costs associated with laboratory testing and follow-up inspections are the responsibility of the applicant. Once approved, a certificate is issued to the manufacturer for approval of equipment and is valid for five years[2]. The Certificate of Approval is renewed upon request so long as the equipment or material has not changed, the requirements have not changed, and the item is still under a continuous follow-up program. Unfortunately, specifics on the approval process are not provided, however, in general the USCG will review all necessary drawings, specifications, proof of follow-up program, and the required testing before approval (U.S. Coast Guard, 2014).

4.1.1.5 Effectiveness

USCG marine inspectors and program managers monitor the number and type of LCM-related deficiencies issued to vessel owner/operators. The USCG has been monitoring these deficiencies for decades, and these efforts have been greatly facilitated with improved information technology, such as the Marine Information System for Safety and Law Enforcement (MISLE) and the Coast Guard Business Intelligence (CGBI) system. While these systems are designed to provide insight on the occurrence of incidences, this information can be connected with inspection and maintenance schedule to better understand the effectiveness of the LCM systems in place by the USCG. In an effort to better understand the effectiveness of their programs, in 2009, the USCG commissioned a study by the Homeland Security Institute to independently assess effectiveness of the USCG’s prevention programs and identify potential improvement and found “[the] Coast Guard’s measures of effectiveness for marine safety include the number of maritime deaths and injuries. These are lagging indicators that are recorded after tragic events occur. To achieve a higher level of effectiveness, it would be very beneficial to identify leading indicators of high-risk situations so that interventions could be achieved before tragic events occur” (Homeland Security Institute, 2009).

4.1.1.6 Liabilities

The risk of legal liabilities to the government regulatory body and to the members of the regulated industry is relative based on a particular incident that may occur as it relates to the life cycle of a critical

[2] The certificate is valid for five years, and the approval will be listed on the internet at http://cgmix.uscg.mil.

component. While a regulation implemented by the USCG may have already undergone an administrative approval process, the effectiveness of the regulation and subsequently the associated liabilities will ultimately be determined once an incident occurs. For example, if an LCM systems' schedule is adhered to regarding a critical component but an incident occurs that results in significant environmental or property damages, then it may be deemed that the LCM systems' policy is insufficient. This conclusion would put significant liability upon the regulatory body, in this case the USCG, to revise their policies and regulations as they relate to that critical component. Similarly, if an incident occurs but instead an industry member did not follow the regulations and policies set forth by the USCG, the industry member could be liable for the impacts due to regulatory non-compliance.

4.1.1.7 Application to BSEE

The model provided by 46 CFR Subchapter Q may be instructive in the improvement of equipment safety that BSEE can apply to its own LCM system. Like the USCG, BSEE could establish a regulatory system that gives BSEE greater control over critical systems being installed on offshore installations. Additionally, BSEE would not have to establish its own standards, but instead incorporate by reference widely accepted industry standards and best practices. Once incorporated by reference, these industry standards and best practices would then carry the force of regulation. BSEE should consult with the USCG's Office of Design and Engineering Standards (CG-ENG). This office is responsible for developing and promulgating national regulations and standards that govern the safe design and construction of vessels and shipboard equipment. While this report provides BSEE with the process behind identification and control of critical equipment, we recognize there would still be a benefit from meeting with personnel within the CG-ENG office and understand some of the nuances of running existing LCM systems.

BSEE should consult with the USCG to explore the possibility of sharing information stored in MISLE. MISLE could help identify the success or deficiencies of an LCM maintenance or inspection schedule as they relate to offshore vessels. The USCG Office of Investigations and Casualty Analysis (CG-INV) has extensive experience analyzing the data in MISLE and could therefore provide assistance to BSEE.

4.1.2 Department of Transportation – Federal Highway Administration

The FHWA is responsible for the construction, maintenance, and preservation of the Nation's Federal-aid (public) highways, bridges, and tunnels. The FHWA works with state and local governments to provide technical assistance to improve the safety, mobility, and innovation of highways and roads. As directed by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), within the FHWA are recommended systems to assist the state manage specific highway assets and processes.

4.1.2.1 History

Based on our research of available resources, the term "Life Cycle Management" is not used in FHWA or DOT documents to specifically define or distinguish such processes. However, careful inspection of the FHWA's systems reveals that LCM systems do exist even, if not termed in such a way. This report will use the term LCM to describe the processes found during our research, comprised of the following systems:

- Pavement Management System (PMS) for Federal-aid highways
- Bridge Management System (BMS) for on and off Federal-aid highways
- Safety Management Systems (SMS)

The 23 CFR 500 sections that provide instructions for the systems listed above are not binding on the state. The state may choose to develop their management systems internally using its own resources or to contract any or all of these management systems to be developed for its use. For example, the 23 CFR 500.205 (d) requires, “Pavements shall be designed to accommodate current and predicted traffic needs in a safe, durable and cost-effective manner,” but does not specify how the state is to meet the requirement.

While the FHWA has three LCM systems, they each have a different history. The PMS began at engineering workshops held in 1980 in Phoenix, Arizona and Charlotte, North Carolina. The discussion held addressed how to measure the condition of pavements to prioritize maintenance planning. Before that, states used their own methodologies to assess and prioritize pavement maintenance within their respective domains. The BMS began as a software tool developed in the 1990’s under an FHWA contract to the American Association of State Highway and Transportation Officials (AASHTO). The SMS was envisioned at a 1981 symposium whose objective was to enhance highway safety through engineering management. The SMS requirements approach was directed by the ISTEA Act of 1991. Further legislation from the Highway Safety Act of 1996 provided comprehensive requirements for safety management that became the responsibility of each state’s governor.

4.1.2.2 Information, Policies, and Procedures

Pavement Management System: The PMS program does not have a specifically identified or defined LCM system; however, the PMS program processes are where the fundamentals of an LCM are found. PMSs were crafted in the 1960s and 1970s by each state independently to cover their pavement maintenance requirements. These programs collected and analyzed data reported during periodic surveys. Recommendations were based on the states’ own acceptance criteria of the data. This changed in 1991 with ISTEA legislation, which has been constantly superseded. The latest is the Moving Ahead for Progress in the 21st Century Act (MAP-21) (FHWA, A Summary of Highway Provisions - MAP-21 - Moving Ahead for Progress in the 21st Century, 2012).

The Moving Ahead for Progress in the 21st Century Act: MAP-21 requires minimum standards for conditions of interstate pavements by requiring a state to devote resources to improve the conditions until the established minimum is exceeded. The Secretary will establish the minimum standard for Interstate pavement conditions, which may vary by geographic region. If interstate conditions in a state fall below the minimum set by the Secretary, the state must devote resources to improve conditions. During the same time as the original ISTEA legislation was the implementation of 23 CFR 500.106

regulations. This CFR recommended that the PMS system should be based upon guidance from the AASHTO.[3]

The parent organization to AASHTO, the American Association of State Highway Officials) was founded in 1914. The name was changed to AASHTO in 1973. Although AASHTO is not a government body, its guidance is incorporated into the 23 CFR 500 regulations, similar to the incorporation of API standards into the CFR regulations for the O&G industry, but with the exception that 23 CFR 500 does not mandate a PMS system. However, the findings made during the research for this report indicated that most, if not all, of the states and the District of Columbia have PMS systems in use. Training programs, seminars, and workshops are available by both the FHWA and AASHTO to support consistency of SMS programs by the states.

Bridge Management System: BMS requirements are shown in 23 CFR 500.107 and state that the BMS system should be based on the AASHTO Guidelines for BMS[4] and utilize modeling to forecast the need for preventative maintenance and predict bridge structural deterioration. The management systems approach was implemented by ISTEA of 1991, which is now MAP-21, signed into law in 2012.

Safety Management System: The requirements for an SMS are found in 23 CFR 500.108, where it states the SMS may be based on the guidance found in *Safety Management Systems: Good Practices for Development and Implementation*. Additionally, MAP-21 requires every state to develop a Strategic Highway Safety Plan (SHSP). Under its Safety Performance, MAP-21 provides that:

- States will set targets for the number of serious injuries and fatalities and the number per vehicle mile of travel. If a State fails to make progress toward its safety targets, it will have to devote a certain portion of its formula obligation limitation to the safety program and submit an annual implementation plan on how the State will make progress to meet performance targets.
- Although MAP-21 eliminates the requirement for every State to set aside funds for High Risk Rural Roads, a State is required to obligate funds for this purpose if the fatality rate on such roads increases.
- The Secretary is required to carry out a study of High Risk Rural Road "best practices."
- States are required to incorporate strategies focused on older drivers and pedestrians if fatalities and injuries per capita for those groups increase.

4.1.2.3 Elements, Best Practices, Lessons Learned

The components of LCM contained in the PMS, BMS, and SMS programs are not developed specific to an LCM system. However, the intent of an LCM is provided by the conduct of periodic inspections,

[3] AASHTO (1985). Guidelines on Pavement Management, American Association of State Highway and Transportation Officials, Washington D.C., 9p.

[4] Bridge Maintenance, Safety, Management, Life-cycle Performance and Cost: Proceedings of the Third International Conference on Bridge Maintenance, Safety and Management, Porto, Portugal, 16-19 July 2006

collection of data, population of a database with the results of those inspections used for comparison to baseline data and determination of degradations, prioritization of repairs and resources; the conduct of maintenance, repair or replacement of pavement; maintenance, repair or reconstruction/ replacement of bridges; or implementation of safety controls as a result of the activities that have been discussed.

PMS details are discussed in 23 CFR 500.106, which suggests that the PMS be based on AASHTO requirements noted below:

- Data collection and management – An inventory of physical pavement features including number of lanes, length, width, surface type, functional classification, and shoulder information.
    - A history of project dates and types of construction, reconstruction, rehabilitation, and preventive maintenance.
    - Condition surveys that include ride, distress, rutting, and surface friction.
    - Traffic information including volumes, classification, and load data.
- Analysis, at a frequency established by the State, consistent with its PMS objectives.
    - A pavement condition analysis that includes ride, distress, rutting, and surface friction.
    - A pavement performance analysis that includes an estimate of present and predicted performance of specific pavement types and an estimate of the remaining service life of all pavements on the network.
    - An investment analysis at network and project levels.
    - An engineering analysis for appropriate sections to include evaluation of how design, construction, rehabilitation, materials, mix designs and preventative maintenance all relate to pavement performance.
- Annual evaluations and upgrades as necessary in conformance with agency policies, practices, engineering criteria, and experience.

The PMS LCM processes involve inspections to measure and determine the deterioration of the pavement over time. The evaluation protocols include use of an International Roughness Index (IRI), measurement of rut depth, faulting and cracking. These measurements are taken periodically as determined by the state. This PMS LCM evaluation process has been evolving by the states but some form of LCM has been adopted and in use since the 1980 workshops (Transportation Research Board, 2003).

For an effective BMS, the 23 CFR 500.107 states that at a minimum, it should include procedures for:

- Collecting, processing and updating data
- Predicting deterioration
- Identifying alternative actions
- Predicting costs
- Determining optimal policies
- Performing short and long term budget forecasting
- Recommending programs and schedules for implementation within policy and budget constraints

BMS LCM processes are provided through the recording of data noted during onsite inspections. The current AASHTO method used to capture this data is American Association of State Highway and Transportation Officials Ware (AASHTOWare) Bridge Management Software, available since 2014. This software allows the user access to:

- Technical references
- Analysis of condition
- Assessment of risk
- Google interface

An example of a state developed process is a web enabled role based relational database structure first implemented in 2009 by Texas. This system allows data to be:

- Directly populated
- Validated prior to acceptance
- Stored electronically
- Easily audited
- Easily available to end users (Freeby, 2013) (AASHTOWare, n.d.)

For SMS, the 23 CFR 500.108 includes a minimum list of requirements that the SMS should meet. Within these requirements the SMS LCM process can be extrapolated as requiring a constant evaluation and reevaluation of driver, road and vehicle interactions. The SMS LCM process can be described as having a goal of reducing driver injuries and destruction of property to the lowest possible achievable through research and evaluation of road conditions to reduce/eliminate all possible unsafe situations. Specifically, this goal is to be emphasized by leadership to keep a focused vision on accomplishment by:

- Development of an SMS for all public roads
- Incorporation of all roadway, human and vehicle safety elements
- Establishing formalized and interactive communications and cooperation among the major highway safety elements
- Using projects and programs identified by use of the SMS in their Highway Safety Plan and Motor Carrier Safety Assistance Program State Enforcement Plan
- Coordination of development, establishment and implementation of the SMS within all agencies responsible for roadway, human and vehicle safety

The LCM structure for SMS is found within the eight elements that are suggested to be incorporated in the SMS:

1. Establishment of short and long term highway safety goals.
2. Establishment of accountability by identifying and defining safety responsibilities of units and positions.
3. Recognition of institutional and organizational initiatives at state and local levels, assessment of responsibilities, establishment of coordination, cooperation and communication mechanisms.

4. Collection, maintenance and dissemination of data necessary for identifying problems and determining improvement needs.
5. Analysis of available data, investigations, evaluations of existing conditions and current standards to assess highway safety needs, select countermeasures, and set priorities.
6. Evaluation of effectiveness of activities.
7. Development and implementation of public information and educations activities to educate and inform the public.
8. Identification of skills, resources and current and future training needs, developing a program to carry out training, development of methods to monitor and implement new technology (Transportation Research Board, 2003).

These processes and follow up implementations are to be self-assessed to determine the appropriate level of effort required and results of those efforts.

The data collected within these management systems appears to align, at least partially, to an LCM system because a dedicated LCM and PMS, BMS, SMS processes are all working toward the same goal – to use carefully selected data parameters, consistently and qualitatively taken to assist management to make informed decisions regarding construction, maintenance and replacement of system assets with regard to safety, budget limitations and time constraints.

4.1.2.4 Role of Industry

The federal government and state DOT are the primary users of PMS, BMS, and SMS programs previously mentioned in this report. However, there are private companies that also provide pavement management systems. AMS Consulting and Agile Assets are two companies that offer PMS solutions to both public and private clients. Agile Assets states:

> *Today you'll find several companies that provide Pavement Management System (PMS) solutions, although the features and sophistication of the offerings vary widely. Most systems can only produce a priority list that delivers one-year budget plans. They do not provide tools for developing pavement network optimization plans that span multi-year periods or that can be used to optimize funding across both programs and asset types. While they often do meet the needs of many smaller agencies, their analytics are generally not sophisticated enough to meet the complex pavement network optimization requirements of larger agencies—like state DOTs. (Nine Key Considerations When Selecting a Pavement Management System, n.d.).*

Non-public clients that may require PMS and BMS include neighborhoods that use private roads, churches, private schools, businesses, and property owners in rural areas.

4.1.2.5 Statutory/Regulatory Elements

The FHWA has not required state DOT to adopt a defined LCM system with prescribed conditions and parameters. Therefore, the FHWA does not have any regulations in place that mandate how a state DOT should implement PMS, BMS, and SMS.

4.1.2.6 Effectiveness

MAP-21 created the National Highway Performance Program as a performance management framework that requires the states to monitor their transportation programs and demonstrate that they support performance outcomes in regards to national goals. Condition assessment includes pavements and bridges. Federal-aid funding of state DOT projects is in support of progress toward achieving the state's performance targets. Also, a Highway Safety Improvement Program (HSIP) requires that the states assess serious injuries and fatalities per vehicle mile traveled and number of serious injuries and fatalities. Performance reports are required to be submitted yearly that detail achievement or failure of the state to meet the goals set forth. Failures require that the state describe actions it will take to achieve its targets.

The results from LCM processes and the recommendations made from their analysis can only be as effective as the type and quality (accuracy) of the database parameters chosen to be acquired and then selected to base transportation decisions on, the ability to scale up or down the response to LCM decisions based on those parameters and the funding made available to each system to perform its job. It was interesting to find that the National Transportation Safety Board (NTSB) does not provide the state DOT's with data collected during investigations undertaken in states where accidents above some threshold have occurred. This data may be available through public means but this project did not find evidence of a direct sharing of information between the NTSB and state DOT PMS, BMS, SMS programs.

According to the Pavement Management Primer on the FHWA's website:

> *Development of pavement management systems can be costly and usually takes several years to produce tangible results. Today, most of the larger highway systems have incorporated pavement management systems into their operating plans. These agencies report that the systems are worthwhile, but that several cycles of data collection are needed to produce significant cost savings in operations and maintenance.* (Federal Highway Administration, p. 3).

During the 1970's several firms began collecting data on pavement management. The Pavement Management Primer describes how these studies revealed five key areas:

1. *Pavement Deterioration—Pavements tend to deteriorate very slowly during the first few years after placement and very rapidly when they are aged. Even though pavement designs and materials varied widely, the deterioration of pavements followed a standard curve. This curve, pavement condition versus age, is shown in Figure 5. (x-axis = number of years, y-axis = quality of pavement in terms of percent)*

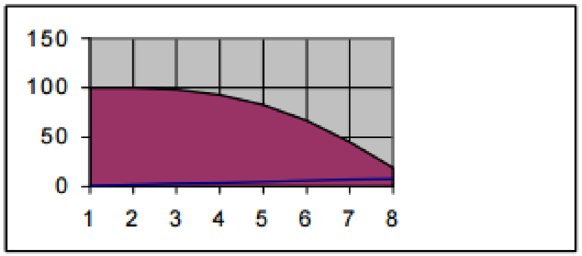

Figure 5: Pavement Deterioration Graph

2. *Costly Maintenance Practices — Typically, State and local governments invest more funds for maintaining highways than for any other public purpose. While much of this is due to the high cost of repairs and heavy usage of the highways, there is strong evidence that some of the high operating costs originate from inappropriate or poorly timed maintenance decisions.*
3. *Preserve versus Reconstruct — Successive years of collecting pavement condition data showed that it was far more economical to preserve roads than to delay repairs and reconstruct roads. The studies further showed that as traffic levels increase the costs of delaying repair work increased greatly. This suggested that the traditional practice of repairing the worst roads first is, in fact, a very expensive way to operate a highway system.*
4. *Data Collection Problems — Data collection by observation was very difficult and was often not objective. Data collection on large highway systems usually required several observers to collect data and led to inconsistencies in the data. This finding led to the development of vehicles that mechanically measure smoothness and other road conditions.*
5. *Using Computers — Early mainframe computers took as much as a week to analyze pavement data and cast some early shadows on the value of the process. With the incredible computing power available on today's desktop computers, these analyses can be run in a matter of seconds. This allows decision-makers to consider numerous "what-if" alternatives.* (Federal Highway Administration, pp. 2-3).

4.1.2.7 Outcomes

The FHWA measures the outcome of its various LCM systems in a few different ways. Of the 52 DOT agencies, 47 of them use IRI for their PMS to measure ride quality for drivers. In addition, these agencies use ten different types of equipment to take measurements. Unfortunately, it is difficult to compare IRI across DOTs since not only does the equipment vary but also the method of measurement. One agency may measure the right-side wheel path only while another may measure only the left side; some agencies report only the worst wheel path and some use an average value from both wheel paths. According to a publication by FHWA, "among the 19 states that provided information about criteria for determining quality levels, the beginning of the unacceptable (poor) level for IRI measurements ranged from 450 inches per mile (7.09 meters) to 45 inches per mile (0.71 meters)" (Finn, 1998). We did not find significant information on how BMS and SMS outcomes are measured across the industry.

4.1.2.8 Data

The effectiveness of LCM processes within the PMS, BMS and SMS systems are measured in statistical data detailing the increase/decrease of maintenance requirements on pavement and bridges, the increase/decrease in vehicle accidents, driver and passenger injuries or death, destruction of properties, the economic impacts due to loss of use (i.e., the I-5 bridge collapse over the Skagit River in May 2013 severed a vital transportation link between Vancouver, BC and Seattle, WA), the monetary value lost in fuel and time during traffic tie ups due to poor engineering design, construction or from repaving deteriorated surfaces or rebuilding/replacing bridges that have worn out. For additional information, refer back to Section 4.1.2.6 Effectiveness.

4.1.2.9 Liabilities

If state DOTs do not properly manage roads using PMS and road conditions become unsafe (i.e., potholes), the state DOT could be liable if a driver is involved in an accident from faulty road conditions. The same could be true for any incidents involving the degradation of bridge safety due to a faulty BMS. While the FHWA's liability may be less severe than the state DOT, the FHWA still risks slight legal liability should the state DOT place blame on the FHWA for not mandating and designing PMS, BMS, and SMS for all state DOTs.

4.1.2.10 Application to BSEE

As mentioned previously, the FHWA does not mandate a defined LCM system within each state's DOT. FHWA believes that the states need to all work toward a common national goal, not simply for each state to meet its own goals. It has implemented requirements that the states show how they plan to meet these national goals for pavement, bridges and safety. It also stipulates that sufficient data be taken to show success or failure of those plans and that states report annually on progress made.

Similar to the common national goal mentality instituted by the FHWA, BSEE may want to consider requiring that their constituents work to goals developed and agreed upon by the BSEE and the OCS O&G Industry towards a common national goal. This leaves flexibility in the regulation to allow the Industry to find the best way to achieve those goals without the encumbrance of meeting well intended, but unnecessary, extraneous rules that add cost and time without adding benefit.

4.2 International Agencies

The information in this sub-section describes the data collected for the following international organizations: New Zealand (Department of Labor), Norway (Petroleum Safety Authority [PSA]), and two organizations from the United Kingdom (UK) (U.K. Health and Safety Executive [HSE]) and (Oil and Gas UK).

4.2.1 New Zealand, Department of Labor

The New Zealand Department of Labor, now known as the Ministry of Business, Innovation and Employment (MBIE), develops policy and regulations, along with delivering other services and advice, to support the overall growth of the country. The MBIE has absorbed the functions of four former New

Zealand Government agencies, the Department of Building and Housing, the Ministry of Economic Development, the Department of Labor, and the Ministry of Science and Innovation. As of 01 July 2012, any inquiries regarding the New Zealand Department of Labor should be addressed to the MBIE. New Zealand does not have LCM systems by this name; rather, they have a SMS that covers both LCM processes and failure reporting.

4.2.1.1 History

The Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 (SR 2013/208) were enacted on June, 5th, 2013. These regulations require organizations requesting to conduct business within New Zealand to develop and establish a SMS.

4.2.1.2 Information, Policies, and Procedures

Drilling contractors that operate within New Zealand's Continental Shelf are typically members of the International Association of Drilling Contractors (IADC). These organizations adhere to the IADC standards and use these standards to conduct business. We assume New Zealand's Department of Labor use these IADC standards, though no specific requirements were stated within their regulations. Further discussion on the IADC and applicable IADC LCM guidelines can be found later in this report.

4.2.1.3 Elements, Best Practices, Lessons Learned

The design, structure, data reporting, and equipment covered by the SMS is solely the responsibility of the specific facility and their operations. Under the Health and Safety in Employment Act (Petroleum Exploration and Extraction) Regulations 2013 (SR 2013/208), Schedule 4 describes elements that operators must address in the SMS to include diagrams of: the installation and secondary structures, layout and configuration of the plant, equipment being used, designated hazardous areas, connections of pipelines, and wells connected to the plant. These elements must also include a description of all types of operations and activities the plant is capable of performing, the maximum number personnel expected to be on the facility and associated accommodations, and emergency evacuation and escape methods, as well as health, safety, and environmental safety precautions.

Under the Health and Safety in Employment Act, the Department of Labor has established and developed Approved Codes of Practice (Best Practices). These codes of practice are not legislation, but deemed statements of good practice under the Act. Failure to follow approved codes of practice is not a violation; however, they are recognized by the New Zealand court system and may be produced as evidence of suitable means of compliance with the Act. Under the Act, there is a specific process of approval prescribed for developing Approved Codes of Practice. Gazette Notices are published announcing proposed Approved Codes of Practice. These are followed by consultation and approval by the Ministry after all consultations by any interested party have been completed. Although Approved Codes of Practice are available to the public, a nominal fee may be charged to obtain copies of the approved codes.

4.2.1.4 Role of Industry

The role of industry is to ensure they meet or exceed the requirements under the Health and Safety in Employment Act (Petroleum Exploration and Extraction) Regulations 2013 (SR 2013/208) Schedule 4. These requirements mandate the development of an SMS. Before becoming operational, it is the responsibility of the Duty Holder and/or Operator to develop a Safety Case describing how the facility will conduct operations. This Safety Case must then be approved by regulators before operations can begin.

It is the duty holder's and or operator's responsibility to ensure all operations specifically follow the requirements described in the facilities Safety Case and report all deviations as may be required by regulations. Reportable deviations may include: serious injuries or fatalities, major accidents, or major environmental damage.

It is also the role of the operators to ensure arrangements are in place for periodic assessments of the facilities safety and materiel integrity. Operators must also schedule independent and competent persons to verify that the safety critical elements of the facility are in place and effective as described in the installations Safety Case.

The primary role of industry is to ensure all regulatory requirements are met and all health, safety, and environmental laws are followed. In the event of serious accidents or significant environmental damage, it is the operator's responsibility to report these incidents as required under New Zealand laws and regulations. Ultimately, the operator's role is to provide a safe and environmentally friendly work environment for employees.

4.2.1.5 Statutory/Regulatory Elements

New Zealand's Health and Safety in Employment Act (Petroleum Exploration and Extraction) Regulations 2013 (SR 2013/208) specifically apply to organizations wishing to conduct O&G production operations in New Zealand. These regulations clearly outline the requirements for the development of a safety case. This safety case must cover all elements of the regulations, and must describe how the organization plans on conducting business. The New Zealand regulations do not explicitly require the development of an LCM system. However, if an organization develops a program, it must clearly articulate how it will develop and manage an LCM system. The regulations do not specify how an organization must develop or manage their LCM system, this responsibility lies solely on the duty holder or the operator.

4.2.1.6 Effectiveness

No specific effectiveness data could be identified during the research for this project; however, New Zealand regulations require a performance monitoring process be included in the SMS. Though New Zealand regulations do not require an LCM system be developed by name, if mandated SMS requirements are met and adhered to, then effectively, an LCM system would be in place. Organizations continue to operate in New Zealand so it can be assumed that the SMS process is effective.

4.2.1.7 Outcomes

No specific data is available to concretely determine the effectiveness of this process. Facilities continue to effectively operate in New Zealand and therefore it can be assumed the process and the facilities performance of LCM are satisfactory. If these programs are incorporated into an organization's safety case, the operators are responsible to ensure these programs are followed as described in the safety case.

4.2.1.8 Data

There is no data available to identify examples of LCM systems for the New Zealand SMS program. The New Zealand regulations do not specify how an operation establishes an LCM system. If an organization has an LCM system, it must be specifically addressed and the process clearly defined in the safety case developed by the duty holder and/or operator. It would then be the responsibility of the duty holder and/or operator to have the LCM system approved as described in the safety case, make all required reports, and make the program available for audit and review as required under New Zealand regulations.

4.2.1.9 Liabilities

There is no information available to determine the effects of legal liability for the New Zealand Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 (SR 2013/208) SMS program (New Zealand Government Parlimentary Council Office, 2013). The duty holder and/or operators are responsible for developing the facility safety case and ensuring all responsibilities associated with the safety case are followed. It can be assumed that most legal liability then rests with the duty holder and/or operator. When the New Zealand government approves a safety case, they are then agreeing with the construct of the facility's plan to operate. This would then imply that the government assumes some liability and responsibility for an organization to begin operations.

4.2.1.10 Application to BSEE

The New Zealand Government's Health and Safety in Employment Act (Petroleum Exploration and Extraction) Regulations 2013 (SR 2013/208) are drafted in such a way that ensures industry covers all required elements of the regulations. Each facility must develop and receive government approval for a safety case in order to begin construction and conduct operations on any facility.

The burden of responsibility and the specifics of how a facility meets the required elements of the regulations are placed solely on the industry organization, as long as the safety case meets the requirements of the regulations and is approved by the New Zealand government. How the elements of safety case are specifically developed and executed are the responsibility of the industry organization requesting authorization to build and operate a facility.

4.2.2 Norway, Petroleum Safety Authority

4.2.2.1 History

Norway's PSA develops, implements, and enforces regulations that pertain to the health, safety, and environmental factors associated with the petroleum activities on the Norwegian Continental Shelf and land-based facilities in Norway. The PSA is an independent government regulator for the Norwegian Petroleum Industry whose offshore regulations rely heavily on national and international standards (Petroleum Safety Authority, 2014). An effort was made a few years back to revise the regulations to become functionally risk-based, with guidelines to suggest how the regulations could be fulfilled. This effort resulted in a significant reduction of regulatory text (from 1,200 to 300 pages) on account of references to standards. In the same timeframe, some of the text in the previous regulations was used as basis for the development of the industry NORSOK standards (International Association of Oil and Gas Producers, 2010).

4.2.2.2 Information, Policies, and Procedures

The O&G industry plays a large role in the development and implementation of regulations and guidelines from the PSA, as discussed in Section 4.2.1.4 Role of Industry. However, the IADC provides Health, Safety, and Environment framework for both onshore and offshore drilling, for which the PSA requires all operators to adhere to, or otherwise obtain an acknowledgement of compliance (American Petroleum Institute, 2013). The IADC's program and frameworks are discussed more thoroughly in Section 4.3.3.

4.2.2.3 Elements, Best Practices, Lessons Learned

The PSA's regulation of the O&G industry is risk-based, rather than systematic and prescriptive. In this capacity, it offers a large degree of flexibility for industry. However, the minimum requirements for health, safety, and environmental plans remain undefined in the Norwegian petrochemical industry. The PSA, in its own regulations and guidelines, states each operator should establish individual minimum requirements for certain issues, but does not elaborate on a regulatory acceptance criteria for those minimum requirements.

From the documentation process detailed in Table 2: Norway PSA Process, it is readily apparent that the PSA upholds an LCM-based mindset in its regulations. Before operations can commence the potential operator must have an approved plan that accounts for health, safety, and environmental factors; risk analysis; emergency preparedness; maintenance; and decommissioning. Once operations begin, the various components of a Failure Reporting System are also required through a documentation process of alert notifications and follow-up reports. The continual development of preventative measures is also maintained through monitoring pollution and the re-evaluation of risks and corrective action plans.

Table 2: Norway PSA Process

Activity	Document Required
Prior to detailed design	- Plans of early phase work management and process

Prior to operation	- Various technical documents - Application for compliance - Application for consent - Management system - Maintenance program - Plans for environmental monitoring - Prepare environmental evaluations - Plan for treatment of waste - Emergency preparedness strategy and plans - Plans covering health, environment, and safety for the development of a petroleum deposit - Analysis of risk - Decommissioning plan
Prior to starting well activities	- Program for drilling and well activities - Action plan for lost well control
Prior to operation	- Plans covering matters relating to health, environment, and safety - Analysis of risk - Decommissioning plan
Incident of violation	- Notification of violation of a safety zone
Prior to drilling operations	- Drilling and well activities - Well program
Ongoing operations	- Annual report of the safety committee - Plans for working hours - All relevant documentation - Reporting of drilling and well activities - Ongoing monitoring of risk analysis, re-analysis of risk, and development of corrective actions - Planning of activities and work processes - Monitoring discharge and risk of pollution - Survey, marine, and seismic data - Plan of implementation of response to pollution
Adverse incident	- Alert notification regarding hazard and accidents - Follow up reports concerning notified hazards and accidents - Reporting of damage to structures and pipelines

(GL Noble Denton, 2010)

As mentioned earlier, the PSA does cite IADC health, safety, and environmental case guidelines as requirements or adhered to with an acknowledgement of compliance in order to obtain a permit of operations (American Petroleum Institute, 2013). In its guidelines, the IADC cites ISO 14001, Occupational Health and Safety Advisory Services (OSHAS) 18001, and ISO 17776 as relevant standards for which it developed some of its recommendations. However, these provide little insight into minimum requirements.

Other regulatory texts the PSA regulations cite include:

- Norwegian Framework Health, Safety, and Environmental Regulations
- Norwegian Activities Regulations
- Norwegian Information Duty Regulations

- Norwegian Management Regulations
- Norwegian Facilities Regulations (GL Noble Denton, 2010).

It should also be noted these standards may have overlap with ISO and API standards.

4.2.2.4 Role of Industry

The development of all PSA regulations and guidelines occurs, to varying extents, under the direction of the Regulatory Forum, formerly known as the External Reference Group for Regulatory Development. The PSA, acting as both chair and secretariat of the Forum, receives representatives from such organizations as the Ministry of Labor, the Norwegian Directorate of Health, the Federation of Norwegian Industries, the Norwegian Ship owner's Association, and the Norwegian Oil and Gas Association (Petroleum Safety Authority, 2015).

The Forum, a "tripartite" collaboration between company, union, and governmental representatives of the Norwegian O&G industry, was first developed in the mid-1980s. Overall, the PSA asserts that the purpose of the Regulatory Forum is to mitigate antagonism between industry and the regulations applied to industry (Safety Status and Signals, 2012). The PSA emphasizes its role to, "secure the necessary risk management" from industry, but also recognizes that industry must agree with the goals behind additional regulation and guidance (Safety Status and Signals, 2012). Specifically, through "discussion, debate, and contributions" from all three parties – industry, unions, and government agencies – the PSA hopes to reach a consensus on all issues brought up in the Regulatory Forum (Safety Status and Signals, 2012).

The Regulatory Forum discusses topics such as:

- Plans for regulatory development;
- Mandates for specific regulatory activities;
- Status reports concerning ongoing regulatory work;
- Collaboration on regulatory development;
- Coordination of external consultation processes;
- Information on principal interpretations;
- Information on standardization work; and
- In-depth presentations on important issues (Petroleum Safety Authority, 2015).

4.2.2.5 Statutory/Regulatory Elements

The PSA has two published documents that pertain to regulations and guidance for the management of petroleum activities. In terms of the required documentation for this report, these regulations and guidelines correspond to ongoing operations and adverse incidents. They contain ten chapters, which deal with topics such as:

- Risk Management
- Objectives and Strategies, Internal Requirements, and the Basis for Making Decisions
- Resources and Processes

- Analyses
- Follow-up and Improvement
- Material and Information
- Notification and Reporting
- Reporting and Information Relating to Offshore Petroleum Activities

Both the documents are published in English and Norwegian, but interpretations of them are only available in Norwegian. In the event of any ambiguity of language, the Norwegian translations take precedence (Petroleum Safety Authority, 2014).

Chapter II: Risk Management

Regulations: The PSA states, "technical, operational and organizational solutions … and barriers that have the greatest risk-reducing effect shall be chosen based on an individual as well as an overall evaluation." Elaborating, the regulations go on to say, "Barriers shall be established that at all times can:

a) "Identify conditions that can lead to failures, hazard and accident situations
b) "Reduce the possibility of failures, hazard and accident situations occurring and developing
c) "Limit possible harm and inconveniences" (Petroleum Safety Authority, 2014).

Guidelines: The guidelines elaborate, "The requirement does not necessarily entail the establishment of a separate management system for health, safety and environment" (Petroleum Safety Authority, 2014).

Overall, the PSA emphasizes that risk management regulations and guidelines should prevent both equipment failure and human error. The LCM mindset manifests itself as risk management is not just about installing proper safety equipment, but involves "organizational solutions" that reflect a risk-based analysis of the entire operational process.

Chapter III: Objectives and Strategies, Internal Requirements, and the Basis for Making Decisions

Regulations: For this chapter, the PSA defines the broader responsibilities of the operator in terms of adhering to general PSA principles. The operator, or "responsible party," must develop "internal requirements that put regulatory requirements in concrete terms, and that contribute to achieving the objectives for health, safety and the environment."

Moreover, the operator must also establish an "acceptance criteria for major accident risk and environmental risk," including cases for:

a) "The personnel on the offshore or onshore facility as a whole, and for personnel groups exposed to particular risk
b) "Loss of main safety functions (as defined in Section 7 of the Facilities Regulations for offshore petroleum activities)
c) "Acute pollution from the offshore or onshore facility,
d) "Damage to third party." (Petroleum Safety Authority, 2014)

The PSA also stipulates these criteria, “shall be used when assessing results from risk analyses” (Petroleum Safety Authority, 2014).

Guidelines: Providing some explicit definitions, the guidelines define a major accident as “an acute incident such as a major spill, fire or explosion that immediately or subsequently entails multiple serious personal injuries and/or loss of human lives, serious harm to the environment and/or loss of major financial assets.” Additionally, environmental risk is defined as “the risk of acute pollution” (Petroleum Safety Authority, 2014).

The PSA grants responsible parties a fair amount of autonomy in setting customized acceptance criteria. However, it must be noted that this also allows for a large degree of flexibility on the part of industry to innovate and adapt existing methods for overall improvement. An approach of this style is heavily dependent on the O&G industry’s willingness not only to comply with the less concrete regulations set forth, but to also orient themselves in a direction that greatly emphasizes health, safety, and environmental best practice adoption.

Chapter IV: Resources and Processes

Regulations: In regards to minimum requirements for certain aspects of the operator’s LCM plan, this chapter asserts it is the operator’s responsibility to do so. The regulations state, “Minimum requirements will be established for manning and competence to safeguard functions where mistakes may have serious consequences for health, safety or the environment, [or] that reduce the likelihood of mistakes and hazard and accident situations developing” (Petroleum Safety Authority, 2014).

Guidelines: The guidelines clarify these minimum requirements can be encompassed by “plans where health, safety and environment are integral parts” (Petroleum Safety Authority, 2014).

Chapter V: Analyses

Regulations: The PSA stipulates that all risk analyses must:

a) Identify hazard and accident situations;
b) Identify initiating incidents and ascertain the causes of such incidents;
c) Analyze accident sequences and potential consequences; and
d) Identify and analyze risk-reducing measures. (Petroleum Safety Authority, 2014).

In addition, “risk analyses shall be carried out and form part of the basis for making decisions when:

a) “Identifying the need for and function of necessary barriers;
b) “Identifying specific performance requirements of barrier functions and barrier elements, including which accident loads are to be used as a basis for designing and operating the installation/facility, systems and/or equipment;
c) “Designing and positioning areas;
d) “Classifying systems and equipment;
e) “Demonstrating that the main safety functions are safeguarded;
f) “Stipulating operational conditions and restrictions; and

g) "Selecting defined hazard and accident situations" (Petroleum Safety Authority, 2014).

Moreover, "emergency preparedness analyses shall be carried out and be part of the basis for making decisions when:

a) "Defining hazard and accident situations;
b) "Stipulating performance requirements for the emergency preparedness; and
c) "Selecting and dimensioning emergency preparedness measures" (Petroleum Safety Authority, 2014).

Chapter VI: Follow-up and Improvement

Regulations: The PSA requires operators collect data on their operations routinely that are "of significance to health, safety and the environment." The relevant data is then to be used for:

a) Monitoring and checking technical, operational and organizational factors;
b) Preparing measurement parameters, indicators and statistics;
c) Carrying out and following up analyses during various phases of the activities;
d) Building generic databases; and
e) Implementing remedial and preventive measures, including improvement of systems and equipment (Petroleum Safety Authority, 2014).

Furthermore, the PSA asserts that operators are to set their own requirements on data collection in regards to "the quality and validity of the data, based on the relevant need" (Petroleum Safety Authority, 2014).

While this approach creates less of a burden on industry than a rigid data set to be reported, the potential shortcomings of these regulations relate to data's quality and overall usefulness. Allowing individual operators to set customized data requirements could result in multiple datasets from the various operators that are incomparable. The PSA does not provide a specific enough definition of the data it seeks, thus feasibly undermining the later analyses of that data.

For incident reporting, the PSA once again grants the operators the ability to set their own criteria "for which situations … must be registered, examined and investigated. Moreover, the operators will also set the 'requirements ... for scope and organization' of the investigation process" (Petroleum Safety Authority, 2014).

Guidelines: The guidelines specify that such investigations should ascertain:

a) The actual course of events and the consequences
b) Other potential courses of events and consequences
c) Nonconformities in relation to requirements, methods and procedures
d) Human, technical, and organizational causes of the hazard and accident situation, as well as in which processes and at what level the causes exist
e) Which barriers have failed, the cause of barrier failure and which barriers should have been established, if applicable
f) Which barriers functioned (i.e., which barriers contributed to prevent a hazard situation from developing into an accident) or which barriers reduced the consequences of an accident
g) Which measures should be implemented to prevent similar hazard and accident situations

(Petroleum Safety Authority, 2014).

Chapter VII: Material and Information

Regulations: Upon an information request from the PSA or another Norwegian governmental agency, the operator must provide a document that contains:

a) A limited and coherent amount of information;
b) Prepared for a specific purpose;
c) Created in a recognized storage media; and
d) Suitable for later use, including reading, playback, display, transmission or other reproduction.

(Petroleum Safety Authority, 2014).

Chapter VIII: Notification and Reporting

Regulations: The PSA must be notified "in the event of hazard and accident situations that have led to, or under slightly altered circumstances could have led to:

a) "Death
b) "Serious and acute injury
c) "Acute life-threatening illness
d) "Serious impairment or discontinuance of safety related functions or barriers, so that the integrity of the offshore or onshore facility is threatened
e) "Acute pollution."

Additionally, the PSA requires that such notifications over the phone must also "be confirmed in writing." For pollution accidents or hazards, reporting must be "in accordance with the Regulations of 9 July 1992 No. 1269 relating to notification of acute pollution, etc. (in Norwegian only)" (Petroleum Safety Authority, 2014).

Therefore, in the case of reportable failures, the PSA provides a more concrete framework for data collection. This, in turn, ensures that all reported data on failures will be comparable for the purposes of identifying trends, common causes, etc. to then correct through regulation.

Chapter IX: Reporting and Information Relating to Offshore Petroleum Activities

Regulations: This chapter deals with required data collection that is sent to other institutions aside from the PSA. This data is not all necessarily based on emergencies, accidents, hazards, or other notable events, but does include "information on monitoring, emissions, discharges and risk of pollution … [and] publicly available information on oceanography, meteorology, earthquakes and full-scale measurements" (Petroleum Safety Authority, 2014).

4.2.2.6 Effectiveness

Measures of effectiveness for the PSA's LCM system regulations and guidelines cannot be divorced from explicit success and failure measures found in the Trends in Risk Level Norwegian Petroleum Activity RNNP failure-based analysis system. Discussed more thoroughly in Task 3, RNNP and its subsequent reports are used to identify areas involving the highest level of risk, and thereby the priorities for surveillance. RNNP includes both qualitative and quantitative indicators on health, safety, and environmental conditions, the data from which is analyzed and published annually.

4.2.2.7 Outcomes

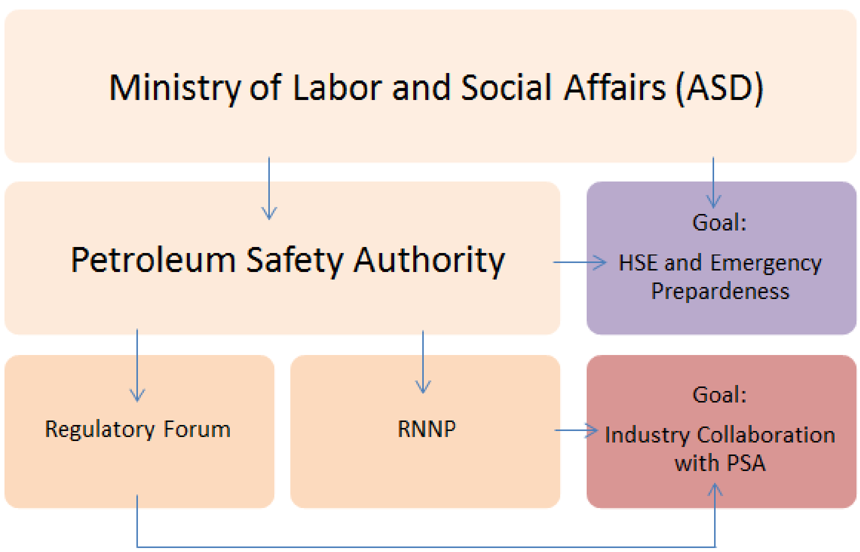

Figure 6: Ministry of Labor and Social Affairs and the PSA

The PSA assists the Ministry of Labor and Social Affairs (ASD) in developing acceptable Health, Safety, and Environment, as well as Emergency Preparedness plans within the O&G industry (see Figure 6). As mentioned previously, the PSA collaborates heavily with industry in the development of regulations that ultimately meet the expectations of the ASD. Therefore, through programs like the Regulatory forum and RNNP, the PSA can readily communicate with industry to ensure these goals are achieved (Eriksson, 2014).

4.2.2.8 Data

As mentioned previously, all data associated with this program's effectiveness come through the RNNP system, a risk-based system used to analyze accidents and failures.

4.2.2.9 Liabilities

The regulations enforced by the PSA are based on the prescriptions of the following legislation:

- The Petroleum Act;
- The Working Environment Act;
- The Pollution Act; and
- Health Care Acts. (Haver, 2008)

The PSA regulates the O&G industry to ultimately ensure it meets the adequate emergency preparedness and Health, Safety, and Environmental goals for the ASD. The PSA has the authority to both issue and revoke operating licenses, in addition to conducting routine inspections of facilities and practices to maintain the specified levels of safety set with the ASD (Eriksson, 2014).

4.2.2.10 Application to BSEE

The PSA's required documentation process incorporates a LCM plan and a Failure Reporting System into one cohesive program. While very thorough and comprehensive in what operators must provide for regulatory purposes, it is not entirely clear what minimal requirements must be met in these documents. Though this allows a certain degree of flexibility for the operators under an LCM framework to tailor to their own needs, the PSA's regulations should explicitly state basic minimum criteria for such documents as emergency preparedness plans, risk analyses, and health, safety, and environmental plans.

In an effort to standardize the O&G industry further, the PSA has also worked to incorporate ISO and API references into its regulatory text. As internationally recognized and pervasively used documents, the ISO and API standards provide the PSA with a well-established foundation for additional regulations in line with its specific goals. The PSA was able to significantly diminish the volume of its own regulatory text with references to ISO and API standards, reducing the amount of legal review and research on the part of drilling companies to obtain a permit of operations, while still maintaining an acceptable level of LCM planning.

4.2.3 United Kingdom Health and Safety Executive

The U.K. HSE is the health and safety regulatory body for Great Britain. The HSE is responsible for developing, managing and enforcing health and safety regulations. The Health and Safety at Work Act of 1974 is the legislative framework the HSE follows to provide guidance, training and education and enforcement as it applies to occupational health and safety in Great Britain.

4.2.3.1 History

HSE's Key Program 4 (KP4) Ageing and Life Extension (ALE) program was initiated in 2010 and followed the Key Program 3 (KP3) Asset Integrity Management (AIM) program, which concluded in 2007. The HSE describes the KP4 as "a forward-looking program of work" (U.K. Health and Safety Executive, 2014) which focuses on:

- Raising awareness of ALE in the offshore industry of the need for specific consideration of ageing issues as a distinct activity within the AIM process
- Undertaking a program of inspections of 'duty holder' approaches to ALE management
- Identifying areas for the improvement of ALE management
- Encouraging the development and sharing of good practices

KP4 evaluated several 'duty holders' drilling in the UK, both onshore and offshore along the following lines:

Safety management systems must have:

- Structural integrity
- Process integrity
- Fire and explosion
- Mechanical integrity
- Electrical, control and instrumentation
- Marine integrity
- Pipelines
- Corrosion
- Human factors (U.K. Health and Safety Executive, 2014).

The HSE carefully defines "ageing equipment" in the scope of continued use stating, "the management of equipment begins with an awareness that ageing is not about how old the equipment is, but is about what is known about its condition, and the factors that influence the onset, evolution and mitigation of its degradation" (U.K. Health and Safety Executive, 2006). Necessarily, with KP4, the HSE sought to establish a more uniform system of evaluating equipment that had exceeded its anticipated life span in terms of an acceptable level of operational safety.

4.2.3.2 Information, Policies, and Procedures

The U.K.'s regulatory body is the HSE. While it does not require environmental cases, nor does it seem to provide guidelines for such cases, the health and safety case must be approved prior to obtaining a permit of operations. Following the UK HSE Offshore Installation (Safety Case) Regulations, 2005, the safety case must:

- Provide enough information to show that the required demonstrations have been made; These demonstrations are in addition to the descriptions and other details required by the relevant schedules to the Regulations

- Show that the installation owner's management system is adequate to ensure compliance with the law in respect of matters within his control; and to ensure the satisfactory management of arrangements with contractors and subcontractors
- Show adequate arrangements for audit and for making audit reports have been established
- Show there is an effective safety management system which ensures the organizational arrangements in place, if fully implemented, will enable the installation owner to comply with all the relevant health and safety laws; and
- Show that hazards with the potential to cause a major accident have been identified and that the risks arising from those hazards are, or will be, adequately controlled (IADC, 2014).

Moreover, the HSE requires that IADC guidelines are followed in the development of safety cases (International Association of Drilling Contractors, 2015). While these guidelines give a general framework for health and safety cases, the HSE's KP4 offers a more in-depth approach for regulating the ageing and life extension of safety critical elements.

Building on KP3, KP4 was proclaimed to be more progressive and collaborative than its predecessor. KP3 "focused primarily on the maintenance management of SCEs [safety critical elements], and reported back on the findings of their condition" (U.K. Health and Safety Executive, 2012). It also "assessed the condition of assets (AIM) at the time of the inspections." The HSE emphasizes strongly that "KP4 is forward-looking, inspecting duty holders' abilities to anticipate and prepare for the integrity challenges of the future, up to cessation of production" (U.K. Health and Safety Executive, 2014). Thus KP3 sought to correct existing problems as they were discovered, while KP4 was designed to anticipate such problems and make adequate adjustments before safety issues arose.

4.2.3.3 Elements, Best Practices, Lessons Learned

Fusing ageing and life extension and asset integrity management into one unified program, the HSE asserts that an effective system under KP4 is "typically risk-based, requiring the duty holder to have a good understanding of the degradation processes and an accurate knowledge of both the condition of a structure and its response in the aged condition. There is also a need to understand obsolescence issues, and an implementation strategy to deal with the likely increasing risk of failure with time, thereby enhancing predictability of deterioration, its detection and assessment" (U.K. Health and Safety Executive, 2014).

In conjunction with the KP4 report, the HSE issued a guide on managing ageing plants. In the report, the HSE asserted "the identification and management of ageing plant issues in relation to process safety is recognized in a number of key risk control systems." Of these systems, elements deemed crucial by the U.K. HSE (2014) for regular inspection and maintenance were:

- Maintenance Management Systems
- Asset Management and Integrity Systems
- Audit and Inspection regimes
- Risk Assessment Management processes
- Management of Change procedures

- Permit to Work
- Responsibilities and Communications
- Training and Competence development

In accordance with HSE RR509 and HSG65 (UK HSE, 2014), the specific considerations listed for each element are listed in Table 3 below.

Table 3: U.K. HSE Element Considerations

Process	Consideration
Maintenance Management	• A well-structured and understood Maintenance Management and Inspection System that interfaces with operations. • Replacement policy in place for HSE critical plant and equipment.
Asset Management and Integrity	• AIMS plan and procedures in place to identify HSE Critical plant and equipment. • Clearly identified and accessible Asset Register documentation to ensure action is taken at the correct intervals. • Reviews at clearly defined intervals to ensure correct data is maintained.
Audit and Inspection	• An audit program is in place to ensure all elements of a management system related to the controlling of ageing plant and equipment issues are maintained. • A operational inspection regime which highlights the need to identify ageing mechanisms such as corrosion, external damage, vibration, exposure to the elements, impingement of harmful releases, identification of dead legs, etc. • Clearly developed corrective action plans with close out tracking systems.
Risk Assessment Management	• Risk Assessment program relating to the impact of failure and the effect of process change • Hazard identification and fitness for service reviews to identify the effect of ageing mechanisms such as wear, corrosion, damage, vibration, pressurization, atmospheric exposures, etc. • Risk based inspection program identifying ownership and rational for change. • Accident/incident investigation procedures with clear action tracking and close out procedures.
Management of Change	• A clearly defined Management of Change procedure. • Clear lines of responsibility and communication to agree and implement change. • Consideration of organizational change and its influence on systems and human factors.
Permit to Work	• N/A
Responsibilities and Communications	• A clear organizational structure with identified responsibilities set out in job descriptions. • Clear internal and external communication routes through regular Engineering/Operational meetings, Contractor/Third Party Management meetings, etc.
Training and Competence	• A competency development program for critical staff containing the ability to recognize ageing mechanisms. • A structured training plan in place. • Job continuity plans to retain job knowledge and operational skills.

KP4 clearly gravitates towards higher level management in inspecting and regulating drilling contractors within the HSE's jurisdiction. The HSE iterated repeatedly in its report that the U.K. is a "mature O&G producing province, with about half the fixed platforms approaching or exceeding their originally anticipated field life" (U.K. Health and Safety Executive, 2014). This distinct issue reinforces the HSE managerial approach, as they mostly regulate well-established drilling entities they have encountered for an extended period. The emphasis on regulating the use of ageing equipment thus demands a more preemptive plan from the duty holder that focuses on a larger picture, rather than reacting constantly with minor repairs.

The HSE makes use of RR 509 and HSG65, in addition to RR 076, RR 253, API RP 571, API RP 574, and API RP 1160. (U.K. Health and Safety Executive, 2014). Beginning with the Research Reports (RR 509, RR 076, and RR 253), all three detail the management and inspection specifics for certain types of machinery.

1) **RR 509: Management of equipment containing hazardous fluids or pressure**
According to the HSE, "the purpose of this report is to increase awareness of the factors to consider when managing equipment containing hazardous fluids or pressure, and to help those responsible for equipment to understand and assess the risks of accumulated damage and deterioration." In favor of generality, RR 509 does not delve into specific details at the equipment level, in an effort to make it applicable "to a wide range of static equipment and associated machinery." The research report emphasizes that "in addition to the engineering aspects, there are important managerial issues that should also be considered," and moreover, the "importance of maintaining documentary information and records throughout equipment life" receives more attention in this report than the actual execution of engineering-related maintenance procedures (U.K. Health and Safety Executive, 2006).

2) **RR 076: Machinery and rotating equipment integrity inspection guidance notes**
RR 076 deals more with inspection and regulatory components than managerial ones seen in the other two research reports. Applicable to offshore facilities, RR 076 provides "guidance for inspectors … and gives sufficient detailed guidance to enable informed and rational judgments to be made during inspection visits to an offshore installation on the state and general health of safety critical areas of machinery and rotating equipment. Additionally, it "covers the development of inspection notes on major safety issues for process machinery and rotating equipment used on offshore installations … [and] contain[s] a review process to be used to assess a complete installation, in order to help an inspector understand the impact of operating culture, and context on the safe operation of machinery and rotating equipment installations" (U.K. Health and Safety Executive, 2003).

3) **RR 253: Piping Systems Integrity: Management review**
RR 253 details "the development of a high level strategy for improving pipework integrity on industrial sites in the U.K.," not just oil drilling sites. With broader themes than the prior two, this report sought to "develop proposals that would help companies reduce the occurrence of pipework failure." It identifies areas of improvement to accordingly achieve this ended by examining

"commonly available information on pipework, reviewed typical failures of pipework and … practical experience from the chemical industry" in order to make its final recommendations (U.K. Health and Safety Executive, 2004).

4) API RP 571: Damage Mechanisms

RP 571 focuses on "setting up effective inspection plans," emphasizing the in-depth approach to signs of damage and its causation, in addition to utilizing Methodologies for Risk-Based Inspection (RBI), Fitness-for-Service, and a Management of Change (MOC) process for the prediction, identification, and correction of damage mechanisms. The API asserts, "many problems can be prevented or eliminated if the precursors to damage are observed and monitored so that any potential damage is mitigated [and] appropriate inspection and/or testing can achieve a proper balance between cost and effectiveness for the relevant mechanisms." Therefore, this recommendation also assists in the "selection of appropriate Non-Destructive Evaluation techniques" for damage prediction and detection (American Petroleum Institute, 2013).

5) API RP 574: Piping System Components

The text of this recommended practice is available for purchase at a list price of $136. The abstract given states:

> *This recommended practice (RP) supplements API 570 by providing piping inspectors with information that can improve skill and increase basic knowledge and practices. This RP describes inspection practices for piping, tubing, valves (other than control valves), and fittings used in petroleum refineries and chemical plants. Common piping components, valve types, pipe joining methods, inspection planning processes, inspection intervals and techniques, and types of records are described to aid the inspector in fulfilling their role implementing API 570. This publication does not cover inspection of specialty items, including instrumentation and control valves* (American Petroleum Institute, 2009).

6) API RP 1160: Managing System Integrity for Hazardous Liquid Pipelines

The text of this recommended practice is available for purchase at a list price of $215. The abstract given states:

> *This recommended practice (RP) is applicable to pipeline systems used to transport "hazardous liquids" as defined in U.S. Title 49 CFR Part 195.2 … This RP is specifically designed to provide the operator with a description of industry-proven practices in pipeline integrity management. The guidance is largely targeted to the line pipe along the right-of-way, but the process and approach can be applied to pipeline facilities, including pipeline stations, terminals, and delivery facilities associated with pipeline systems.*
>
> *This recommended practice (RP) outlines a process that an operator of a pipeline system can use to assess risks and make decisions about risks in operating a hazardous liquid pipeline in order to achieve a number of goals, including reducing both the number and consequences of incidents.*

The document includes a description of an integrity management program that forms the basis of the RP (American Petroleum Institute, 2013).

4.2.3.4 Statutory/Regulatory Elements

The HSE states that "ALE is a global issue, with other offshore regulators active," such as BSEE and the Bureau of Ocean Energy Management in the United States (U.S.), the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) in Australia, the PSA in Norway, and the State Supervision of Mines in the Netherlands (Energy Division of HSE's Hazardous Installations Directorate, 2014). However, little information could be found on the specific ALE regulations that all regulatory bodies, except for the PSA, had in place. The PSA's literature on the subject partially stems from direct collaboration with the HSE regarding ageing and life extension, starting with the HSE's KP3 program.

The HSE also utilizes good practice guides in asset management set forth in the Publicly Available Specification (PAS) 55 and Contract Research Report (CRR) 363/2001. The Institute of Asset Management defines PAS 55 as a standard that "provides objectivity across 28 aspects of good asset management, from lifecycle strategy to everyday maintenance (cost/risk/performance). It enables the integration of all aspects of the asset lifecycle: from the first recognition of a need to design, acquisition, construction, commissioning, utilization or operation, maintenance, renewal, modification and/or ultimate disposal." Comprised of two parts, PAS 55 gives "definitions of terms in asset management [and] requirements specification for good practice," in addition to "guidance for the implementation of such good practice" (Institute of Asset Management, 2008).

Contract Research Report 363/2001 "discusses the best practice for application of RBI as part of plant integrity management, and its inspection strategy for the inspection of pressure equipment and systems that are subject to the requirements for in-service examination under the Pressure Systems Safety Regulation 2000 (PSSR)." To elaborate, CRR 363/2001 describes PSSR as "a risk-based approach to be used for the planning of inspection. Notably, these regulations "allow the Duty Holder and Competent Person flexibility in deciding upon a suitable written scheme of examination in terms of the equipment to be inspected and the frequency and nature of examination" (Wintle, Kenzie, Amphlett, & Smalley, Best practice for risk based inspection as a part of plant integrity management, 2008).

4.2.3.5 Effectiveness

The HSE uses separate templates for onshore and offshore inspections. While there is significant overlap in the evaluation styles, they nonetheless require separate assessments in order to address their differences. Effectiveness appears to be measured on the various scales employed by these templates.

Onshore Templates:

The HSE developed a "Traffic Light" system on a scale of 1-6, with 5 and 6 being red, 3 and 4 being amber, and 1 and 2 being green. Through a series of questions, certain benchmarks are expected in the answers to determine a duty holder's score on the categories of ALE Policy and Leadership, ALE

Organizing, ALE Performance Measurement, and ALE Auditing and Review of Performance. Table 4 below breaks down each number in an evaluation:

Table 4: U.K. Health and Safety Executive Color and Compliance Codes

Score	Color Code	Compliance	Action
6	Red	Serious Non-Compliance	Court Proceedings Recommended
5	Red	Significant Non-Compliance	Enforcement Notice Served
4	Amber	General Non-Compliance	Letter and Changes Made to Intervention
3	Amber	Partial Compliance	Letter
2	Green	General Compliance	Verbal Advice
1	Green	General Compliance	No findings

(U.K. Health and Safety Executive, 2014).

Offshore Templates:

The offshore templates consist of five areas:

- Review of documentation covering ageing/degradation mechanisms.
- Review of equipment/system physical condition.
- Discuss the impact of the ageing/degradation of the equipment/system with the personnel who operate and maintain it.
- Assess how the known ageing/degradation has been used to modify the inspection plan. It is expected this will be achieved by discussion with the onshore Technical Authority after the offshore inspection.
- Assess how the known ageing/degradation has been used to inform the equipment/system estimated life and used as an input into field life extension decisions. It is expected this will be achieved by discussion with the onshore Technical Authority and Asset manager after the offshore inspection (U.K. Health and Safety Executive, 2014).

While most employ the 1-6 scaled traffic light system seen in the onshore templates, a few use a three-tiered system of red, amber, and green to each denote one level of satisfaction. It is unknown at this time how long these systems of evaluation have, in a comparable form, existed in the HSE, but these templates reflect the KP4 program objectives started in 2010.

While the KP4 program concluded in 2013, the HSE has not conducted a follow-up study assessing the most current progress of ALE policies for its evaluated duty holders. In its final report, the HSE made recommendations for itself in continuing the goals of KP4, specifically to “continue to be involved with the industry, and maintain the positive dialogue which has taken place during the KP4 program for the long-term safety of offshore workers.” It also planned to:

- Continue to recognize the importance of ALE management through interventions
- Continue to work with Step Change in Safety to encourage workforce involvement
- Monitor and review duty holder ALE performance
- Continue to collaborate and support the offshore industry to identify and share good practices (U.K. Health and Safety Executive, 2014)

4.2.3.6 Liabilities

The HSE has the ability to fine duty holders who do not comply with their standards. That being said, the KP4 program sought to establish a new precedent in terms of ageing and life extension management, and served mainly to implement a new guidance procedure in which, based on the evaluation templates, the severest punishment for non-compliance was a court proceedings recommendation (see Section 4.2.3.5 Effectiveness).

4.2.3.7 Applicability to BSEE

The KP4 program applied a top-down approach to establishing ALE and AIM guidance in the HSE's jurisdiction. The findings of KP4 focused on such topics as leadership and preparedness for ALE, Audits, data management, and developing further ALE guidance. With an emphasis on collaboration, the KP4 program proved useful for the HSE in fostering ALE management. Therefore, if initiating a program with little prior foundation such as KP4, BSEE could benefit from studying how the HSE successfully executed a high-level introduction of new practices into industry.

The inspection templates seem particularly beneficial as they introduce a more elaborate grading scheme than a simple pass/fail system. The six tiers partitioned into three groups offer more information on why a duty holder manages an acceptable or unacceptable rig. Moreover, the system to determine grading reinforces the positive dialogue HSE noted when reporting on the completion of KP4.

4.3 Industry

The information in this sub-section describes the data collected for the following organizations: ISO, API, American Waterway Operators (AWO), Industry Representatives, and IADC.

4.3.1 American Waterways Operators

The AWO is a trade association that represents the tug and towing vessel industry. The AWO's Responsible Carrier Program (RCP) improves marine safety and environmental protection in the tugboat, towboat, and barge industry by establishing preferred industry operating principles and practices as voluntary standards of conduct. While the standards outlined in the RCP meet or exceed current USCG standards for barge and towing vessel operations, they do not necessarily constitute an exhaustive catalogue of all potential safety practices that any particular company should undertake.

4.3.1.1 History

The RCP has been in place since 07 December 1994 when the board of directors of the AWO unanimously approved the establishment of the program. In April 1998, the AWO changed its organizational bylaws to require members to demonstrate a "good faith commitment" with RCP as a condition of membership. In January 2000, 100 percent of the remaining member organizations were in "audited compliance" with RCP. To achieve compliance, member organizations were given until 01 January 2000, or within two years of joining the AWO. Thirteen chose not to comply with the new requirements (American Waterways Operators, 2013).

In 2004, the board of directors voted to reduce the timeframe for compliance to one year from joining the AWO. In 2008, the board voted to remove the "good faith commitment" clause from the bylaws and require AWO members to undergo an AWO-certified audit of their program. In 2012, AWO entered into an agreement with the Towing Vessel Inspection Bureau (TVIB),[5] which began training and certifying RCP auditors and developing resources to enhance the quality and consistency of RCP audits (American Waterways Operators, 2015).

4.3.1.2 Information, Policies, and Procedures

Each company must determine for itself its own operational needs and the range of safety measures necessary to protect its employees, the public, and the environment. The RCP is not intended to supplant any existing safety procedures that a company may have in place in excess of the standards outlined herein. Finally, while the objective of the RCP is to enhance safety and environmental protection in the tugboat and towboat industry, no program can be considered a solution to completely eliminate injuries, accidents, or pollution incidents. The pursuit of better, safer operations through continuous improvement is the AWO's goal (American Waterways Operators, 2013).

On 07 December 1994, AWO unanimously approved the establishment of the AWO RCP as a code of practice for association member companies. Within AWO's Strategic Plan, AWO 2000, it states their overall goal is to "improve industry safety and environmental protection by establishing preferred industry operating principles and practices," utilizing the process of industry self-examination which began in the wake of the September 1993 derailment of the Amtrak Sunset Limited (American Waterways Operators, 2013).

The RCP serves as a template for AWO member companies to use for developing company-specific safety programs, including maintenance programs. These programs must be consistent with applicable law and regulation, but can also incorporate sound operating principles and practices not currently required by law or regulation. Overall, these individualized programs are practical and flexible enough to reflect a company's unique operational needs. In addition, RCP combines a set of common principles and practices that can be observed by a company regardless of its trade or its size, with an emphasis on company-specific policies and procedures, which may vary significantly both between and among industry sectors. For instance, the RCP requires all crewmembers onboard vessels be properly trained; however, training programs do not necessarily have to be USCG-approved, but must be formal and well documented (American Waterways Operators, 2013).

In 2008, AWO determined that as requirement for membership, its current and prospective members should achieve compliance with the AWO RCP and undergo an AWO-certified audit of their program within two years of joining. Failure of a company to complete its required RCP audit within the time allowed would result in AWO immediately removing the company's certification of RCP compliance and a termination of membership (American Waterways Operators, 2013).

[5] http://www.thetvib.org/

The industry-initiated RCP is a safety management system for tugboat, towboat, and barge companies that provides a framework for continuously improving company safety performance. AWO members of all sizes use the RCP to develop company-specific safety and environmental policies and programs tailored to the industry's unique operational environments. The program complements and builds upon existing government regulations, requiring company safety standards that exceed those required by federal law or regulation. Since 2000, compliance with the RCP has been a condition of AWO membership (American Waterways Operators, 2013).

4.3.1.3 Elements, Best Practices, Lessons Learned

Under the RCP requirements, each towing company is mandated to develop and document written policies and procedures tailored to their organization and operations. These policies are to cover, at a minimum, the items outlined below. Companies must then implement and abide by these policies in conducting their operations, including ensuring their employees are aware of, and trained in, those policies and procedures which affect their job responsibilities. In addition, all AWO carrier members are required to comply with all applicable Federal laws and regulations concerning marine safety and environmental protection (American Waterways Operators, 2013).

In regards to ***Vessel Maintenance and Administration***, AWO focuses on 10 particular areas:

1) Vessel Operating Policies and Procedures
2) Safety Policy and Procedures
3) Security Policy and Procedures
4) Environmental Policy and Procedures
5) Incident Reporting Procedures
6) Emergency Response Procedures
7) Internal Audit and Review Procedures
8) Vendor Safety
9) Organization and Levels of Authority
10) Personnel Policies and Procedures (American Waterways Operators, 2013)

1) Vessel Operating Policies and Procedures: AWO RCP states that companies are to develop specific operating and maintenance procedures. The vessel-specific operating procedures will depend on vessel size, cargo, and trade, along with procedures for making horsepower/tow size decisions. Vessel maintenance procedures are to include maintenance schedules, qualifications and training requirements for maintenance personnel, procedures to correct deficiencies identified during maintenance, and maintenance record retention and reporting requirements.

2) Safety Policy and Procedures: AWO RCP mandates that companies have an implemented safety policy that includes an accountability for and commitment to safety. A company must also provide safety training, safety drills, and safety meetings (including station bill) accompanied by training on safe use of equipment, corrective action processes, and hazard communication procedures (right to know) under 29 CFR 1910.1200.

3) Security Policy and Procedures: AWO RCP states that a company is to establish a company-wide security policy.

4) Environmental Policy and Procedures: AWO RCP states that a company is to have a company-wide environmental policy that includes garbage disposal requirements, procedures and documentation, handling of waste oil, oily bilge slops, used filters, hazardous waste disposal and handling, sanitary systems, and handling of sewage procedures.

5) Incident Reporting Procedures: AWO RCP states that a company is to have an incident reporting procedure that contains guidance for personal injury, oil or hazardous substance spill, vessel accidents, bridge, lock, or dock allusion and grounding incidents.

6) Emergency Response Procedures: AWO RCP states that a company is to: have emergency response procedures for personal injury responses; develop a spill response plan and/or contingency plan; and develop procedures for vessel accident response, onboard emergency response training, drill procedures, and operator incapacitation procedures.

7) Internal Audit and Review Procedures: AWO RCP requires a company to establish procedures for conducting annual internal audits, which include procedures to ensure compliance with applicable Federal laws and regulations concerning marine safety and environmental protection, personal injury investigation procedures, spill investigation procedures, vessel accident investigation procedures, and communication procedures for disseminating lessons learned.

8) Vendor Safety: AWO RCP requires companies to establish procedures for the evaluation of subcontractors and vendors providing services.

9) Organization and Levels of Authority: AWO RCP requires a company to have appropriate levels of authority and accountability including vessel master and crew. In addition, the AWO RCP requires the company to designate a person(s) ashore having direct access to the highest level of management.

10) Personnel Policies and Procedures: AWO RCP requires a company to have certain policies and procedures regarding its employees including: a formal hiring policy; physical exams or a physical standards policy; and a robust drug and alcohol policy, pursuant to 46 CFR 16.210.

In regards to ***Coastal Equipment and Inspections***, AWO looks at many different aspects as part of its requirements within the RCP, of particular note are:

1) Hulls
2) Machinery
3) Firefighting and Lifesaving Equipment (American Waterways Operators, 2013)

1) Hulls: AWO RCP requires documented inspections of each vessel operated by an RCP member company by an appropriate company representative or third-party personnel. Such inspections are an important component of sound vessel maintenance and a LCM system.

2) Machinery: AWO recommends that each company develop a vessel maintenance program as outlined in the Management and Administration section of the AWO RCP. At a minimum, this program should cover the following: propulsion systems (all major propulsion machinery, including engines, reduction gears, clutches, controls, shafting, bearings, and other items prone to wear), steering systems (all components), miscellaneous auxiliary systems and electrical systems (which should be properly labeled). Alarms and Gauges are also to be looked at by the company to ensure operability of the following alarms at a minimum: (1) Main engine water temperature; (2) Main engine lube oil pressure; (3) Bilge alarm and; (4) Generator water temperature alarms.

3) Firefighting and Lifesaving Equipment: AWO recommends through RCP that a check-off report should be turned in or a log entry made at least quarterly verifying that the required firefighting and lifesaving equipment is present and in proper working order.

4.3.1.4 Statutory/Regulatory Elements

AWO members of all sizes use the RCP to ensure company-specific safety and environmental policies meet minimum industry standards in excess of those required by federal law or regulation. The RCP is not a government regulated program; it is internally managed and regulated by the AWO.

All AWO carrier members are required to be in compliance with all applicable federal laws and regulations concerning marine safety and environmental protection as a baseline. All company policies and procedures should be consistent with applicable law and regulation and with the guidelines provided in the Equipment and Inspection and Human Factors sections of the AWO RCP (American Waterways Operators, 2013).

The RCP incorporates best industry practices in three areas: company management policies, vessel equipment LCM and human factors. The comprehensive program requires companies undergo an audit by an independent third party-auditor to verify compliance (American Waterways Operators, 2015).

4.3.1.5 Effectiveness

All RCP auditors were required to complete TVIB-led recertification training in 2013. By year’s end, 68 new and recertifying auditors had been trained, 23 AWO members received training in best practices for internal auditing and 37 auditors completed Responsible Care Joint Audit Program training conducted by the American Chemistry Council. TVIB also worked with the RCP Standards Board to develop a new RCP management audit worksheet to assist auditors and AWO Members in preparing for an effective audit (American Waterways Operators, 2013). There are 222 member organizations in the AWO. All member organizations are RCP certified; 10 member organizations are operating on a 1st year provisional certification, the remaining 212 member organizations are RCP certified from 2015 through 2019, depending on their most recent certification audit.

4.3.1.6 Outcomes

The flow chart below (Figure 7) establishes the current procedure of an RCP audit from start to finish. The items highlighted in blue are the corresponding documents an auditor will need to use throughout the audit process (American Waterways Operators, 2013).

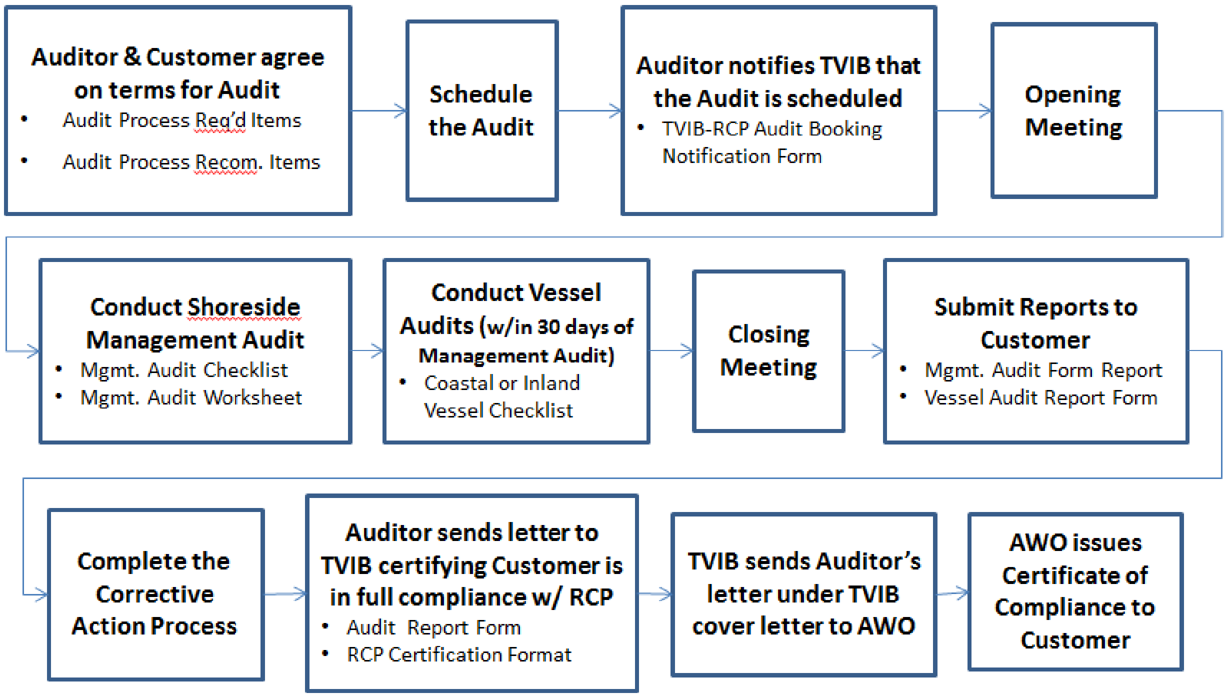

Figure 7: RCP Audit Flow Chart (Towing Vessel Inspection Bureau, 2014)

4.3.1.7 Data

Companies maintain their own data from their system internally. AWO mandates audits of the system to certify compliance with the RCP but does not collect or use the data. The audits are specifically conducted to ensure compliance with the program.

4.3.1.8 Liabilities

Because the AWO is a trade association, the RCP is based on improving marine safety and environmental protection rather than superseding USCG standards. Therefore, while the elements of the RCP may meet or exceed USCG standards, each industry member has its own responsibility to determine their own operational standards and therefore the liability is upon the various industry members and not on the AWO or USCG. Unless Federal or state law were to lessen liability or exempt an AWO member in compliance with the RCP, the full panoply of pre-existing environmental and maritime/shipping liability laws and statutes apply to AWO members carrying out the RCP. Our extensive search of those Federal or state laws found no lessening or exemption of potential liability. Because of time and cost constraints and the small likelihood of finding anything on the state level, a full search of all state statutes in the 20+ states with waterways was not attempted to definitively answer this question.

Numerous states have environmental and maritime/shipping statutes that differ from Federal statutes. If the Federal statutes provide more extensive environmental protection and tort liability, the provisions of state statutes are usually preempted by the Federal legislation, requiring the more stringent or higher Federal standards to be applied in the state. Almost all carry civil and criminal penalties and liability for oil spills. Some states have more stringent environmental laws and higher tort liability than Federal law. If that is the case, the more stringent state statutes must be followed unless it is determined that the Federal enactment was intended to preempt the state laws.

AWO RCP, if fully followed by any particular company in the industry, may very likely lessen the likelihood of non-compliance with these laws and of any illegal bilge release or oil spill, thus lessening the likelihood of liability for that company. Yet the full panoply of potential civil and criminal penalty liability remains, along with a myriad of potential maritime or common law tort litigation arising from the private sector.

Environmental civil liability is often strict liability; it usually arises simply through the existence of the environmental violation, without regard to what the responsible party knew about the matter. Environmental criminal liability is triggered through the existence of some level of intent. Because of this distinction, most of the environmental crimes that EPA investigates involve "knowing violations" of the law, which are usually classified as felonies. A "knowing violation" is one in which the defendant is aware of the facts that constitute the violation – an instance in which conscious and informed action brought about the violation, rather than, as would be the case with a civil violation, an accident or mistake. For example, an intentional decision to discharge oil or pollutants into a river could be a "knowing violation," and thus criminal, without regard to the defendants knowledge of the law.

Any voluntary industry sponsored compliance and self-inspection regime that a company has a track record of following could arguably tip the balance in any litigation or administrative determination toward a finding of "an accident or mistake" where conflicting evidence may not fully convince an administrator, judge, or jury of a "willful and knowing" violation. Thus, a self-inspection or voluntary compliance regime like the RCP could lessen the potential liability of criminal penalties or criminal negligence.

4.3.1.9 Application to BSEE

The AWO RCP maintenance and inspection requirements and policies could be a useful framework for BSEE to consider adopting. For example, the Executive Branch has just recently decided to permit petroleum exploration and drilling in the Atlantic OCS. According to the Wall Street Journal, on 27 January 2015, "…the government would hold drilling lease sales between 2017 and 2022 off the coast from Virginia to Georgia…" This decision will, over time, greatly increase BSEE and USCG responsibility and constructively reduce their inspection forces. BSEE and USCG cannot expect that increases in inspector staffing will keep pace with the expansion of offshore activity into the Atlantic OCS. Existing responsibilities can expect to be "triaged" to make room for newer, exigent priorities.

Most likely, BSEE will not be able to simply increase the number of third party inspectors with limited authority. Consideration must be given to vesting non-governmental agencies or individuals with authority to perform all BSEE inspector functions under supervision and oversight of qualified, experienced BSEE inspectors. Two examples of programs with extensive third party inspection authority are the Federal Aviation Administration (FAA) Designated Examiner program, the Institute of Nuclear Power Operations and AWO RCP.

4.3.2 American Petroleum Institute

The American Petroleum Institute is a unique industry trade association in the scope and variety of global activities its members undertake—from drilling crude oil, to refining it into various petroleum products, to the distribution and sale of products.

4.3.2.1 History

ABS Consulting has identified three API sets of standards which pertain to LCM. These are: API 16AR – API Monogramed Parts, API Q1 – Quality Management Specifications for Manufacturing Organizations and API Q2 – Quality Management Specifications for Service Organizations. As a general principal, API standards are revised with regular frequency. For example, API 16AR was recently revised in 2013 and API 14B was revised in 2012. Similarly, API standards for LCM – Standards Q1 and Q2 – were updated in June 2014 and December 2011, respectively.

4.3.2.2 Information, Policies, and Procedures

API is a standard setting organization. API sets standards and encourages industry to adhere to these standards. Under the current regulatory environment, many of the industry standards set by the API and ISO are adopted into regulatory law by BSEE. Briefly summarized, the API documents are:

1. API 16AR – API Monogrammed Parts
2. API Q1 – Quality Management Specifications for Manufacturing Organizations
3. API Q2 – Quality Management Specifications for Service Organizations

Details on the API guidelines which pertain to LCM are as follows:

API 16AR - API Monogrammed Parts

API standard 16AR provides detailed LCM Guidelines for the providers of API monogramed parts. In it, the API lays out the guidelines for LCM systems for new, individual, API monogrammed products or system parts throughout their functional life cycle. That is to say, for a piece of drilling equipment to be formally API monogramed, the design, production, and repair shops must be fully certified under API standards (QPI Q1, API 16 and API 16AR). The product owner must also agree to maintain accurate records and conduct scheduled maintenance from a competent 3rd party. Finally, the operator must approve a LCM plan developed by a Life Cycle Management Service Provider. The LCM plan covers all aspects of a parts service life including maintenance and decommissioning (American Petroleum Institute, 2014).

API LCM standards are also reflected in API Q1 and API Q2. API Q1 governs manufacturing standards and API Q2 governs service standards. Since both manufacturing and service can be thought of as having "life cycles," we included both. As BSEE is already familiar with API standards Q1 and Q2, these standards are only briefly summarized.

API Q1 – Quality Management Specifications for Manufacturing Organizations
API standard Q1 establishes minimum quality management system requirements for organizations that manufacture products or provide manufacturing-related processes under a product specification for use in the petroleum and natural gas industry. API Q1 calls for a comprehensive quality management system with written policies, planning and communications, management roles with clear authority, and organizational resource specifications and documentation requirements. Stringent product realization requirements are included, as are mandates for monitoring, measurement and analysis (American Petroleum Institute, 2014).

API Q2 – Quality Management Specifications for Service Organizations
API Specification Q2 is similar to API specification Q1. With the exception of manufacturing, Q2 provides guidelines for all aspects of petrochemical project and service delivery, including the following:

- Critical Success Factors
- Service Quality Planning
- Mandatory Procedures
- Defined Personnel Competency and Training Requirements
- Risk Assessment and Management
- Contingency Planning
- Supplier Criticality
- Preventative Maintenance of Service Equipment
- Change Management (MOC)
- Inclusion of Outsourced Suppliers in Internal Audits

While the term 'Life Cycle Management System' is not explicitly used in API Q2, the actions it recommends, including preventative maintenance, change management and risk assessment, are all part of a comprehensive LCM program (American Petroleum Institute, 2011).

4.3.2.3 Elements, Best Practices, Lessons Learned

For API, a review of the LCM guidelines points to a number of commonalities that regulatory agencies such as BSEE should be aware of. These are:

1. Decisions Support Capability: API standards reviewed here contain explicit provisions for LCM systems to provide feedback on management relevant metrics, such as product quality assurance or accident reduction.
2. Monitoring and Control: Monitoring and control is a common theme in the API standards reviewed in this work. For example, API standard Q1 makes explicit reference to management systems with clear lines of responsibility.

While API standards are comprehensive in regards to the theoretical systems they lay out, it is unclear how effectively they govern actual business practices between players in the offshore petrochemical industry.

4.3.2.4 Statutory/Regulatory Elements

The API uses a consensus based system drawing on expert input to formulate and update their guidelines (John, 2014). The degree to which all relevant safety data is incorporated into LCM guidelines appears to be a matter of interpretation. Often, ISO standards pull heavily from similar API standards (see Section 4.3.2 American Petroleum Institute).

4.3.2.5 Effectiveness

In order to determine the effectiveness of API's programs, ABS Consulting spoke with our in-house Subject Matter Experts (SMEs). In general, the SMEs reported that API does not conduct formal scientific studies of the effectiveness of their programs, but instead rely on the committee system to update and revise as needed.

However, industry feedback on API standards does come through the API committees' process. The API committees consist of industry members who participate in the development and updating of the standards. The committee forms the voice of all interested stakeholders, including the industry. It is an ongoing process, receiving feedback, comments and issues. If the standard is already published, feedback can be communicated to API's industry representatives, who then pass the information along to the committee chairman for discussion at the next committee meeting. If the committee is no longer active, API maintains a small group of individuals responsible for collecting and addressing inquiries and feedback from industry.

In addition, API has a quality management system which tracks and updates their standards setting process. All API standards are subject to review every five years. As part of this review, API frequently checks on all of the standards that are active to see what the status is and if there any questions or comments from the industry that need to be addressed. Part of the five year review is making sure that all comments from industry are addressed, or at least discussed (John, American Bureau of Shipping Oil and Natural Gas Senior Engineer, 2014).

4.3.2.6 Liability

Since API standards are voluntary and provide standards that meet or exceed legal requirements, API will, most likely, not be held liable in case of a failure of an operator's LCM system. Given that API is setting a standard, the liability of compliance will be on the operator to implement the guidelines and parameters provided in the standard.

4.3.2.7 Applicability to BSEE

ABS Consulting's review of API industry standards suggests that API standards for LCM are only as effective as oil industry operator's commitment to adhering to standards. For example, API standards 16AR, Q1 and Q2 are often associated with registration or accreditation status. If petrochemical industry operators lack commitment to quality or are just "going through the motions" regarding LCM standards without real organizational commitment to quality, then standards will be ineffective. This is particularly an issue when industry-driven auditing or enforcement standards are weak.

While API 16AR, Q1 and Q2 accreditation is likely a marker for good LCM practices, BSEE should consider supplementing API life cycle standards with additional metrics, reporting requirements, or regulatory stipulations to counteract any potential tendency of industry operation management to merely "go through the motions."

4.3.3 International Association of Drilling Contractors

Since 1940, the IADC has exclusively represented the worldwide O&G drilling industry. With the broad mission of improving performance for the drilling industry, membership is open to any company involved in O&G exploration, drilling or production, well servicing, oilfield manufacturing or other rig-site services (IADC, 2014).

4.3.3.1 History

The IADC mission is to improve performance for the drilling industry while increasing safety. Since 1940, IADC has exclusively represented the worldwide O&G drilling industry. With the broad mission of improving performance for the drilling industry, membership is open to any company involved in O&G exploration, drilling, production, or well servicing (IADC, 2014).

4.3.3.2 Information, Policies, and Procedures

The IADC hosts a yearly Asset Management and Reliability Conference focused on sharing best practices for LCM. The association's informal definition of asset management revolves around "keeping major structures robust and keeping O&G contained where they belong," while reliability ensures that "equipment and systems work properly when we need them" (Mine Safety and Health Administration, 2014). The IADC promotes LCM by offering a "Knowledge, Skills and Abilities" (KSA) competency program. This program allows workers or companies to access "maintenance procedures and the proper operation of specific types of equipment, depending on the rig type and environment" (Mine Safety and Health Administration, 2014). By providing the drilling industry with a tool to better choose human capital with the experience needed to operate valuable equipment, the IADC helps operators ensure their drilling equipment is operated correctly and they help extend the equipment's performance life.

In addition to these Asset and Reliability and KSA programs, this section will focus on the most widely used IADC LCM system, *Health, Safety, and Environment Case Guidelines*. In January 2014, the IADC issued *Health, Safety, and Environment Case Guidelines* for both Mobile Offshore Drilling Units (MODU) and Land Drilling. While the IADC explicitly states, "the Guideline is not compulsory, its use is recommended as a demonstration of good industry practice for Drilling Contractors." Therefore, while not an authoritative or mandatory interpretation of universal international drilling regulations, both onshore and offshore, these guidelines serve as a general framework upon which drilling contractors develop a Health, Safety, and Environment case tailored to their individual practices. As the IADC is an international body, the varying jurisdictions its members may fall under is acknowledged with a strong emphasis multi-party communication to generate the specifics of a contractor's Health, Safety, and Environment case.

The IADC proposes a series of expectations and possible demonstrations a contractor may undertake in order to prove it possesses an effective Health, Safety, and Environment case. The guideline states that "the scope and arrangements for providing assurance internally and a demonstration externally [is] that:

- "There is an effective Health, Safety, and Environmental management in place for managing major hazards, other workplace hazards, and environmental aspects;
- "All potential hazards have been identified; and
- "Risks associated with these hazards have been identified, assessed, and managed with any residual risks reduced to tolerable levels" (IADC, 2014, pp. Section 1, Page 3).

While the guideline defines major hazards, various types of risk, and other similar vocabulary, it does not give a qualitative or quantitative measure on perceived effectiveness. Once again, as IADC members interact with different regulators and experience non-uniform policies and legislation, the guideline emphasizes that, in terms of regulatory requirements, "arrangements for monitoring and confirming that effective Health, Safety, and Environment management has been implemented and maintained … [in] compliance with applicable regulatory requirements" must be pursued (IADC, 2014, pp. Section 1, Page 6).

The lack of explicitly stated standards of effectiveness or success of a particular Health, Safety, and Environment case proves the biggest drawback of these guidelines. While the IADC has made considerable efforts in standardizing the creation and implementation of a Health, Safety, and Environment case, the relative capabilities of these cases do not have a baseline against which they can be assessed. The guidelines nevertheless offer a thorough framework and enable a large degree of flexibility when developing a Health, Safety, and Environment case to suit the contractor's needs. That being said, in order to assure consistency in execution amongst its members, the IADC must issue a complementary report that measures successful and unsuccessful practices.

4.3.3.3 Elements, Best Practices, Lessons Learned

The Health, Safety, and Environment case guidelines detail Management System, Risk Management, Emergency Response, and Performance Monitoring, in addition to thorough descriptions of the major equipment being used in the drilling process. Beginning with the Management System, the guideline defines it as "a structured set of elements … that are intended to ensure that the operations of an organization are directed, planned, conducted, and controlled in such a way as to provide assurance that the objectives of the organization are met" (IADC, 2014, pp. Section 2, Page 1). The objectives are those set by the contractor, the client, and/or another "external stakeholder." While regional regulatory agencies are not mentioned here, the implication of a third-party stakeholder seems to point in that direction.

Risk Management is defined in the guidelines as, "the coordinated activities to direct and control an organization or activity with regard to risk" (IADC, 2014, pp. Section 4, Page 8). Refining this broad interpretation, the guidelines recommend the application of the Structured Hazard Identification and Control Process. After employing this process of identifying hazards, evaluating risk, and identifying risk reduction measures, the final outcome in the Health, Safety, and Environment case should include:

- "The identification method used to make the inventory of Hazards.
- "Listings of hazards, equipment, areas, chemicals and substances, responsibilities, tasks and measures of control to limit the exposure from such hazards.
- "Through a baseline survey, exposure levels, as appropriate, should be assessed against a relevant standard to determine if they are tolerable and safe.
- "Identification of Company exposure/risk tolerance level standards.
- "How and at what exposure/risk level actions are taken and where improvement is necessary." (IADC, 2014, pp. Section 4, Page 16)

The Emergency Response section of the guidelines offers a generalized approach that emphasizes proper management, effective communications and an emergency command hierarchy, as well as proper training of workers and an evacuation plan. None of these suggestions cite any regulatory policies in particular, and rely heavily on the contractor to develop specific practices and plans in order to effectively respond. While this, yet again, does allow for tailoring to suit the need, it seems the IADC also relies on regulatory agencies to enforce certain specifics in regards to the overall response process.

Performance Monitoring is actually classified as a Management System Element, but nevertheless warranted its own section in the Health, Safety, and Environment guidelines. The guidelines break Performance Monitoring into three parts: Periodic Monitoring; Audit and Audit Compliance; and Verification of Health, Safety, and Environmental Critical Activities/Tasks and Equipment/Systems. No regulations are cited in the Periodic Monitoring suggestions, but Audit and Audit Compliance explicitly states that details of an audit scoping should take into account, amongst other things: drilling contractor requirements, flag state requirements, coastal state requirements, and classification society requirements. Verification lists similar requirements when getting equipment certified (IADC, 2014, p. Section 6).

4.3.3.4 Statutory/Regulatory Elements

The Health, Safety, and Environment case guidelines cite ISO 14001, OSHAS 18001 and ISO 17776 as relevant standards for which it developed some of its recommendations.

According to ISO, ISO 14001 "sets out the criteria for an environmental management system and can be certified to. It does not state requirements for environmental performance, but maps out a framework that a company or organization can follow to set up an effective environmental management system" (International Organization For Standardization, 2014). The fact that the IADC faltered in stating explicit requirements and standards for Health, Safety, and Environment case effectiveness appears more justified, as even the ISO has not stringently defined baseline standards.

OSHAS 18001 “sets out the minimum requirements for occupational health and safety management best practice.” However, the ISO is currently developing a new standard intended to replace OSHAS 18001, called ISO 45001, to be published in 2016, that will work in conjunction with ISO 9001 (Quality Management) and ISO 14001 (Environmental Management), which are due in 2015 (Occupational Health and Safety Management (U.K.), 2014).

ISO 17776 pertains mostly to the Risk Management section of the guidelines. The ISO states,ISO 17776 “describes some of the principal tools and techniques that are commonly used for the identification and assessment of hazards associated with offshore O&G exploration and production activities…. It provides guidance on how these tools and techniques can be used to assist in development of strategies both to prevent hazardous events and to control and mitigate any events that may arise” (International Organization For Standardization, 2014).

The guidelines state that the Risk Management section therefore, “provides a step-by-step guide to applying a risk management process based on ISO Standard 17776.” Additionally, while no specific requirements are listed, the guidelines also state that the Risk Management Process “has been developed to comply with requirements of International Maritime Organization (IMO) [and] International Safety Management Code” (IADC, 2014, pp. Section 4, Page 3).

Appendix 4 of the Health, Safety, and Environment case guideline attempts to delineate a country-by-country approach for the regulatory authorities in:

- Australia
- Netherlands
- Denmark
- Italy
- U.K.
- Norway
- Germany
- New Zealand

Copious amounts of legislation are cited and detailed in Appendix 4. For the purposes of relative brevity, this report will discuss the regulatory authority legislation for Australia, Netherlands, Denmark, U.K., Norway, and New Zealand, as these agencies were of particular interest in Task 1.

Australia’s regulatory body is the National Offshore Safety Authority (NOPSA). NOPSA stipulates that “in order for a safety case to be accepted by NOPSA, it must be submitted to NOPSA by the operator. The safety case may relate to one or more of the ‘stages of life of the facility,’ which means one or more of construction, installation, operation, modification, and decommissioning.” Additionally, NOPSA “must accept the Safety Case if there are reasonable grounds for believing that it is appropriate to the facility, it complies with requirements and that any validation meets the legislative requirements.” The relevant Australian legislation for safety case requirements are *Petroleum (Submerged Lands) Management of*

Safety on Offshore Facilities Regulations, 1996. While these only cover safety, the Australian government does have environmental guidelines for an environmental case (IADC, 2014).

The Netherlands' regulatory body is the State Supervision of Mines. The health and safety cases submitted to the State Supervision of Mines undergo a three-part review to assess adequacy. Upon submission, "the first phase is an administrative overview to ensure the document is complete and generally complies with legislation. The second phase is a detailed technical review to ensure the demonstrated case for safety is robust. The third phase is the on-site/location verification that the written word is put into practice." The primary legislation that guides this process of health and safety case adequacy is Working Conditions Act 1998. While environmental cases are not explicitly addressed, the IADC asserts that "integrated Safety, Health, and Environment management system[s] … are also commonplace" for the Netherlands (IADC, 2014).

Denmark's regulatory body is the Ministry of Climate, Energy, and Building in the Danish Energy Agency (DEA). Health and safety cases must be "submitted to the DEA as part of the documentation needed for the application for an operation permit." Additionally, all health and safety cases must have plans "covering major hazards, occupational health and safety hazards, and other health conditions." While "an environmental case is not required … an environmental emergency response plan for oil spills is required." The main requirements for a health and safety case are detailed in the *Offshore Safety Act, Consolidated Act no. 520 on Safety* (IADC, 2014).

The U.K.'s regulatory body is the Health and Safety Executive. While it does not require environmental cases, nor does it seem to provide guidelines for such cases, the health and safety case must be approved prior to obtaining a permit of operations. Following the *Offshore Installation (Safety Case) Regulations, 2005*, the safety case must:

- Provide enough information to show the required demonstrations have been made. These demonstrations are in addition to the descriptions and other details required by the relevant schedules to the Regulations
- Show that the installation owner's management system is adequate to ensure compliance with the law in respect of matters within his control; and to ensure the satisfactory management of arrangements with contractors and subcontractors
- Show that adequate arrangements for audit, and for making audit reports, have been established
- Show that there is an effective safety management system which ensures the organizational arrangements in place, if fully implemented, will enable the installation owner to comply with all the relevant health and safety laws
- Show that hazards, with the potential to cause a major accident, have been identified and that the risks arising from those hazards are, or will be, adequately controlled" (A4-58) (IADC, 2014).

As previously discussed in Section 4.2.2, Norway's regulatory body is the PSA. Health and safety cases submitted to the PSA must obtain an Acknowledgement of Compliance (AOC), which the contractor must submit with additional documentation in order to be permitted to operate. The AOC is "a statement that … technical standard and the applicant's organization and management system are in compliance with safety and working environment requirements in Norwegian legislation" (A4-87). The relevant legislation is Regulations relating to management of petroleum activities, and does include a section on environmental cases (IADC, 2014).

As previously discussed in Section 4.2.1, New Zealand's regulatory body is New Zealand Petroleum and Minerals. Under the legislation titled *Health and Safety in Employment Amendment Act,* health and safety requirements stipulate that the case must provide an overview of the arrangements in place for:

- Monitoring performance in relation to the management of major accident hazards and other workplace hazards;
- Reporting, analyzing, and learning from incidents and work-related illness;
- Independent and competent persons to audit the management of major accident hazards and other workplace hazards;
- Independent and competent persons to verify that safety-critical elements remain effective;
- The periodic assessment of the installation's integrity; and
- Periodically reviewing the effectiveness and suitability of the major accident policy and safety management system (New Zealand Legislation, 2013).

Additionally, operators are required to maintain an emergency response plan that, "must take into account the operating and environmental conditions," though no specific environmental case is required (New Zealand Legislation, 2013).

4.3.3.5 Effectiveness

The IADC published Version 3.6 of the *Health, Safety, and Environmental Case Guidelines for Mobile Offshore Drilling Units* (MODU) in January 2015 and version 1.0.1 of *Health, Safety, and Environmental Case Guidelines for Land Drilling Units* in July 2009. As a measure of the guidelines' effectiveness, the IADC received the Carolita Kallaur Award for Outstanding International Safety Leadership in December 2007, presented by International Regulators Forum. "The award recognized IADC's contribution to improving safety in drilling operations, through the development of the Health, Safety, and Environment Case Guidelines" (IADC, 2014).

The IADC's guidelines have been adopted by the ten regulators (IADC, 2014). From our research conducted on the regulatory bodies discussed above, in addition to the IADC guidelines, effectiveness is gauged on a pass/fail or accept/reject system, namely that the Health, Safety, and Environment case is adequate.

4.3.3.6 Outcomes

The IADC's LCM system can be measured by the continual increase in members and decrease in the frequency of both injuries and operational failures in the participating drilling industry. The decrease in injuries can be seen via either the worldwide Lost Time Accident rate or IADC's own Incidents Statistics Program (ISP), which identifies causes and trends of drilling industry injuries. The previous section regarding Effectiveness also depicts how well regulators are satisfied with IADC's case guideline LCM system. The Health, Safety, and Environment guidelines have gone through a number of revisions, indicating that the IADC needed to provide crucial updates over time in order to adapt to the changing needs of the industry.

4.3.3.7 Data

In regards to the program's effectiveness as it relates to the avoidance of safety-related consequences, IADC manages an ISP that tracks the frequency and incidence rate for lost time on the job due to safety related occurrences. According to IADC's Five Year Summary Report, the incidence and frequency rate of reported lost time for the industry as a whole has decreased significantly from 2009 (FREQ = 1.88, INCD = 0.37) to 2013 (FREQ = 1.29, INCD = 0.26) (IADC, 2014) (Refer to the Task 3 Report: Appendix E). The use of IADC's Safety Alerts and other Health, Safety, and Environment case guidelines have aided in the reduction of these rates and an overall increase in safety for the drilling industry.

4.3.3.8 Liabilities

The Statutory/Regulatory Elements section above details the Health, Safety, and Environment case requirements for the regulatory bodies of Australia, Netherlands, Denmark, U.K., Norway, and New Zealand. All six adhere to IADC guidelines as mandatory practice, so the Health, Safety, and Environment case guidelines are, effectively, the generalized legislation for drilling contractors in these respective areas. While the IADC states that the case guidelines, "represent a voluntary, core set of principles which can be applied to any drilling unit regardless of geographic location" (IADC, 2014), the association may risk being liable should a domestic or international regulator find its guidelines inaccurate or incomplete. However, our research did not find any instance of the IADC being liable for any drilling incident. Rather, the IADC is often portrayed as actively defending its members in the drilling industry against private and public critics and lobbying in the interest of the drilling industry.

4.3.3.9 Application to BSEE

Overall, the IADC provided a very comprehensive set of guidelines that delineated Health, Safety and Environment cases for drilling contractors. Their international clout is evidenced by the regulatory bodies that hold these guidelines as a requirement, and accordingly BSEE should take note of the attention to detail that the IADC employed when developing said guidelines. They allow for a certain level of flexibility in tailoring the Health, Safety, and Environment cases for specific operations of varying scales, and in doing so promote efficiency and avoid redundancy and unnecessary paperwork. The crucial drawback is that these guidelines only have a binary measure of success. The biggest improvement would be to introduce a more widespread measure of success for Health, Safety, and Environment cases, in order to promote higher standards of execution and encourage more effective practices.

4.3.4 International Organization for Standardization

The ISO is an independent, non-governmental organization with 165 member countries and a Central Secretariat based in Geneva, Switzerland. ISO has published more than 19,500 International Standards, which provide specifications for products, services and systems to ensure quality, safety and efficiency (ISO, 2014).

4.3.4.1 History

The ISO is an industry standard setting organization. [6] Under the current regulatory environment many of their standards are adopted into regulatory law by BSEE. In general, the ISO updates their standards every five years (International Organization For Standardization, 2014).

4.3.4.2 Information, Policies, and Procedures

Applicable standards that have been identified for LCM are the following:

1. ISO 20185 – Production Assurance and Reliability Management
2. ISO/Technical Specification (TS) 29001 – Petrochemical Quality Management Systems
3. ISO 15926 – Life Cycle Data for O&G Production
4. ISO 15663 – Life Cycle Costing for O&G Production

ISO Guidelines Pertaining to LCM

ISO LCM guidelines are reflected in numerous published standards documents. In order to provide a comprehensive yet manageable snapshot of ISO standards, ABS Consulting focused primarily on ISO finalized standards which directly pertained to the management of offshore O&G infrastructure. These standards include: ISO 20815 – Production Assurance and Reliability Management; ISO/TS 29001 – Petrochemical Quality Management Systems; ISO 15926 – Life Cycle Data for O&G Production; and ISO 15663 – Life Cycle Costing for O&G Production.

ISO 20815 – Petroleum, Petrochemical and Natural Gas Industries – Production Assurance and Reliability Management

ISO 20815 introduces the concept of production assurance within the systems and operations associated with exploration drilling, exploitation, processing and transport of petroleum, petrochemical and natural gas resources. It focuses on production assurance of O&G production, processing and associated activities and provides guidelines for the analysis of reliability and maintenance of the components.

ISO 20815 also provides processes and activities, requirements and guidelines for systematic management, effective planning, execution and use of production assurance and reliability technology. This is to achieve cost-effective solutions over the life cycle of an asset-development project structured around production-assurance, management for optimum facility economy through all of its life cycle phases, while also considering health, safety, planning, execution and implementation of reliability technology and operation improvement (International Organization For Standardization, 2014).

[6] The API also has industry advocacy goals and statistical reporting functions in addition to standard setting roles.

ISO/TS 29001 – Petroleum, Petrochemical and Natural Gas Industries – Sector-specific Quality Management Systems – Requirements for Product and Service Supply Organizations

ISO/TS 29001 defines the quality management system for product and service supply organizations for the petroleum, petrochemical and natural gas industries. It is essentially an adaptation of ISO 9000 (Quality Management Systems) designed for the needs of the Oil and Natural Gas industry. ISO/TS 29001 outlines a process approach whereby customer requirements are integrated with business process in a holistic and robust manner.

ISO/TS 29001 also calls for a "Plan-Do-Check-Act" (PDCA) to be applied to all processes. PDCA can be briefly described as follows:

- Plan: Establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organization's policies.
- Do: Implement the processes.
- Check: Monitor and measure processes and product against policies, objectives and requirements for the product and report the results.
- Act: Take actions to continually improve process performance (International Organization For Standardization, 2014).

ISO 15926 – Industrial Automation Systems and Integration—Integration of Life Cycle Data for Process Plants Including O&G production

Unlike ISO 20185 and ISO/TS 29001, ISO 15926 is a series of documents containing both published standards and technical specifications. It contains a number of substantive standards as well as a number of ancillary and supporting documents. The overall objective of ISO 15926 is to provide a common lingua franca so large petrochemical organizations have a uniform basis for data management to support the life cycle activities and processes of production facilities. Briefly summarized, the key components of this series are:

- Part 1: Overview and Fundamental Principles
- Part 2: Data Model (International Organization For Standardization, 2014)
- Part 3: Reference data for geometry and topology
- Parts 4, 5 and 6: Use and definition of reference data for process plants
- Part 7: Implementation methods for the integration of distributed systems: Template methodology (International Organization For Standardization, 2014)
- Part 8: Implementation methods for the integration of distributed systems: Web Ontology Language (OWL) implementation (International , 2014)
- Part 9: Implantation standards for web servers, facades and security
- Part 10: Test Methods
- Part 11: Industrial Usage Guidelines (International Organization For Standardization, 2014).

Because petrochemical processing plants can contain a large number of parts and systems, ISO 15926 focuses on a highly generic, conceptual data model designed to be used in conjunction with reference data: standard instances that represent information common to a number of users, process plants, or both.[7]

ISO 15663 Petroleum and Natural Gas Industries – Life Cycle Costing

ISO 15663 outlines an important element of LCM, cost estimation. Similar to other ISO published documentation ISO 15663 comes in three parts. Part 1 (ISO 15663-1) contains information on methodology, Part 2 provides guidance on application of methodology and calculation methods, and Part 3 provides implementation guidelines.

ISO 15663 pertains to LCM as cost is a key aspect of LCM in the private sector. In general, ISO 15663 has broad application to management decisions including: defining process concepts, equipment siting locations, project execution strategies, weighing health, safety and environmental factors, system concept and sizing, selecting equipment types, implementing equipment configurations, maintenance and operational strategies, determining staffing levels, facility modification decisions and asset reuse/disposal decisions (International Organization for Standardization, 2014) (International Organization For Standardization, 2014) (International Organization for Standardization, 2014).

4.3.4.3 Elements, Best Practices, Lessons Learned

The ISO LCM guideline points to a number of commonalities for regulatory agencies to be aware of:

1. *Need for a Comprehensive Data Reporting Structure*: It is notable that ISO has devoted entire guideline documents to data formatting, sharing and reporting (International Organization For Standardization, 2014). This data reporting structure needs to be generic enough to accommodate the vast diversity of hardware and system components in a typical offshore oil or gas production facility, as well as be readable by other industry actors or associated agencies.
2. *Decisions Support Capability*: ISO standards reviewed here contain explicit provisions for LCM systems to provide feedback on management relevant metrics such as product quality assurance or accident reduction (International Organization For Standardization, 2014).
3. *Systems Integration*: This is a key component found in almost all of the LCM standards reviewed as part of the ISO section of this report. For example, ISO standard 29001 suggests a PDCA feedback system. The main goal of the PDCA system is to both integrate work functions, as well as provide management feedback over those functions (International Organization For Standardization, 2014).
4. *Monitoring and Control*: Monitoring and control is a common theme in the ISO standards reviewed in this work. For example, ISO 20185 outlines procedures for systematic management (International Organization For Standardization, 2014).

4.3.4.4 Statutory/Regulatory Elements

ISO uses a consensus-based approach, broadly similar to the API approach. ISO uses expert input to formulate and update their guidelines (John, American Bureau of Shipping Oil and Natural Gas Senior

[7] See http://15926.org/index.php for a user based discussion of ISO 20185 implementation.

Engineer, 2014) (International Organization For Standardization, 2014). The same issues and strengths posed in API standards would also apply to the implementation of ISO standards.

4.3.4.5 Effectiveness

ABS Consulting's review of ISO life cycle standards suggests at least one possible concern with ISO standards, which is the definition of "quality" is not definitive. Some LCM systems in compliance with ISO standards could simply gauge whether processes are being followed, instead of whether processes are the correct process or in need of improvement. Furthermore, when unique technical solutions are involved in the creation of a new part, ISO does not validate the robustness of the technical solution, which is a key part of advanced quality planning. ISO accreditation is an important indicator of quality, but does not necessarily guarantee high quality parts.

4.3.4.6 Liability

ISO standards face the same liability issues as API standards, as discussed in Section 4.2.3.6 Liabilities. As a voluntary standard, industry members would bear the liability of a failure or the capture of data according to their implementation of the ISO standard.

4.3.5 Industry Representative Company

ABS Consulting interviewed industry representative employees and discussed how receptive industry would be to potential new regulatory requirements involving LCM systems and Failure Reporting Systems, current and acceptable required data collection, how industry currently views present requirements, and what potential recommendations industry might have that could be mutually beneficial to industry and regulators. The following are discussion points and feedback covered during the interview.

Industry is in need of clear and specific definitions and levels for critical systems, critical components, and critical equipment. There are multiple variations and interpretations of similar definitions developed and used by other industry entities. These variations in definitions cause confusion, making it difficult for industry to have a clear understanding of the terms, how they are applied, and to what the definitions apply to. Specific, clear definitions developed by BSEE and vetted by industry will give a clear lexicon from which regulators and industry can follow. These definitions, once developed, should be included in any new or updated regulatory frame work. This will provide a clear understanding of terminology; a foundation from which industry can develop LCM and Failure Reporting System programs; a baseline for BSEE to develop and update new and current regulations, policies and programs; and a baseline for industry and BSEE to conduct a risk assessment to identify high risk critical systems, critical components and critical equipment.

There are no regulations requiring LCM systems in the O&G industry. Because these programs are not required, many of the smaller industry organizations do not have programs, nor do they desire to start them. It is believed that only the larger O&G companies are using integrated LCM and Failure Reporting System programs to enhance their business case, but the smaller organizations have a "run things until they fail and then fix it" mentality. Smaller companies typically do not have the resources or the desire to manage these programs. It is believed that many of the larger oil companies would be accepting of the requirements for LCM and Failure Reporting System programs, though smaller companies would most likely strongly object to any requirement they believe to be burdensome, costly, and ineffective.

There is a strong sense of wariness in the O&G industry, both within the industry itself and towards regulators. Industry competitors fear sharing LCM information can lead to loss of competitive advantage. Fear of retribution by regulators for reporting failures or accidents is prevalent throughout the industry, though some reports are made for minor issues. This is a significant issue for subcontractors as well. Their concerns are if they report issues, they could lose their contract and be replaced by another organization. Because of this, most subcontractors may not make reports of any kind. Because of this mistrust, using a third party unbiased independent organization to gather information as required by regulatory requirements could serve several purposes:

1. It could serve as a clearing house of information, which would relieve BSEE of the resource constraints of managing, organizing, and responding to potentially massive amounts of data, and eliminating the perception of a lobbying group pressuring regulators.
2. It could alleviate any actual or perceived biases industry currently holds.
3. The third party organization would track and ensure industry organizations meet and follow all regulatory requirements. The independent third party would be under contract and make reports to BSEE and industry as required, and would provide transparency and develop trust between industry and regulators.

Industry does not want to report information if there will be no timely feedback on the information provided. Industry does not have the time or resources to spend on collecting information, sending it to BSEE, and then not receiving feedback in a useful time frame. Receiving feedback from data collected six months, one year, or two years later provides industry with limited useable or valuable feedback. A third party organization would provide BSEE with the resources to quickly vet actionable issues and provide industry with feedback in a reasonable and acceptable time frame. One potential obstacle could be receiving authorization from the Office of Management and Budget to use a third party organization to manage a regulated data collection and dissemination program. It is believed, however, that industry would be receptive of BSEE using a third party organization for this purpose.

Industry representatives suggested that a hybrid approach (See Section 6 Recommendations) to regulations should include a form of a Safety Case and prescriptive requirements. This would give industry the flexibility to develop their programs based on the specific needs of their operation, as well as give BSEE the regulatory enforcement capabilities to effectively manage the requirements prescribed in the regulations. These regulations would need to include requirements for a specific list of critical components, such as: Blowout Preventers (BOPs), electrical systems, cranes, health and safety items, and other systems that could be considered high risk components and should be part of a prescriptive list that has been developed by BSEE and vetted through industry as accurate and reasonable. It was recommended that BSEE include industry representatives in the development of any new regulations.

This would give industry the opportunity to provide valuable input into the regulatory development process.

Industry would want to know specifically what new regulatory requirements would be considered, and specifically how these requirements would be enforced. For example, new regulations would be required that identify specific data reporting requirements and what specific data would be required to be submitted. Reporting information that is considered high risk is extremely important and should be collected as long as the information is handled according to Confidential Business Information (CBI), Sensitive Security Information (SSI), and any other regulated protocols. Establishing high risk reporting criteria would require a risk assessment to identify specific critical components and processes that both BSEE and industry agree should be considered high risk and reportable.

In order for industry to provide any form of accurate or useable data, BSEE will have to develop specific regulations with specific reporting requirements. These reporting requirements will need to be prescriptive enough to gather specific information and focused on high risk issues. They should not require reporting on issues of lessor risk or importance. Working with industry to identify those areas that could be considered high risk and reportable would be very valuable and provide significant industry input into the requirements. In order for industry to fully comply with these requirements, BSEE will have to mandate these requirements in regulations.

4.3.5.1 Liabilities

Government regulators will always have liability and responsibility of enforcing laws and regulations. Ensuring industry adheres to regulatory requirements where health, safety and environmental risk are factors is the biggest challenge. Resource constraints where regulators may not be capable of meeting the enforcement requirements could have a significant impact on government liability in the event of a significant incident.

Industry shares in liability as well. Industry has the responsibility to manage health, safety and environmental risk by adhering to regulatory requirements. In the event of a catastrophic event where human life is lost, significant injuries occur and/or a major environmental incident occurs, industry will share, if not be totally liable for the incident.

5. Findings

LCM has been in use in the O&G industry since the 1960s. However, there appears to be little consistency in the application of LCM principles.

5.1 Information, Policies, and Procedures

Most of the regulatory organizations reviewed for this study require the development of LCM systems in some form. It is also apparent that all of the regulatory communities reviewed for this study are supplementing their regulatory structures with references to standards or guidelines developed by well-known domestic and international standards organizations. Where the regulatory approaches differed widely were the degrees of prescriptiveness applied to the design of LCM systems. The regulatory communities' approaches to LCM systems represent a spectrum that ranges from comprehensive and specific regulations, to less prescriptive and open-ended performance or risk-based regulations. It is important to note that most of the agencies reviewed for this study utilized some elements of both approaches, but to varying degrees.

Agencies like the Nuclear Regulatory Commission (NRC) and the Pipeline and Hazardous Materials Safety Administration (PHMSA) have taken an approach that lends toward detailed regulatory criteria for the development of LCM systems, but nevertheless with some elements of risk-based criteria. Towards the middle of the spectrum is the USCG, which has regulations that are in equal parts prescriptive and risk-based, in an approach that strongly resembles an LCM. However, the USCG's approach is less comprehensive and has a less coherent application when compared to the NRC's and PHMSA's LCM systems.

Alternatively, at the other end of the spectrum is Norway's PSA, the New Zealand's Petroleum and Minerals agency, and the U.K.'s HSE "Safety Case" approach. This approach constructs an LCM framework through the perspective of Health, Safety, and/or Environmental goals. These agencies also utilize approaches that are more dependent on risk-based guidance than on specific regulations. For example, the "Safety Case" approach requires the operator of an offshore facility to identify the hazards and risks and then leaves it to the operator to describe how they control risks.

These findings make sense when viewed in the context of a holistic risk spectrum. The NCR and PHMSA regulate industries that deal with exceptionally hazardous materials and processes that have the potential for serious consequences to large populations. As a result of the associated dangers, these activities are highly scrutinized. Consequently, industry's willingness to strictly adhere to regulation and guidance may appear diminished when compared to the nuclear and hazardous materials industries. The variation noted in the prescriptiveness or flexibility in LCM systems reflects the regulatory bodies' attempts to maximize compliance from industry.

5.2 Elements, Best Practices, Lessons Learned

As we have highlighted before there is no single model for LCM systems that neatly spans the entire scope of offshore operations. However, when looking at the totality of the models presented in this report, there are some overlapping commonalities. The following list of LCM model elements (or phases) represents a compilation of the LCM systems discussed in this report. These elements include the LCM process from planning to decommissioning:

- Requirements: This phase includes analyzing needs and documenting functional requirements. It also includes analyzing current infrastructures, as well as identifying the alignment with strategies.
- Design: In this phase, requirements are transformed into detailed system designs and performance criteria that address:
    - Functionality

    - Reliability
    - Survivability
    - Dependency and interaction with other systems
    - Maintenance
    - Prevention of hazards
    - Well containment
    - Fire and explosion prevention and control
    - Escape and refuge
    - Evacuation and rescue
- Build and Test: In this phase, system designs are converted into a functional system and integrate with other systems. Those systems are then tested to determine interoperability. This would include:
    - Perform interdisciplinary design verification
    - Provide for verification by competent third parties
    - Verify the work by contractors and subcontractors
    - Test systems and equipment before installation
    - Test functionality before commissioning
    - Develop inspection and maintenance procedures in advance of commissioning
    - Develop operational procedures specific to systems and equipment
- Operation and Maintenance: For this phase, systems or equipment are in operation and carrying out their intended functions. Elements of the LCM should include:
    - System and equipment maintenance data collection and management processes
    - Failure reporting and corrective action systems
    - Predictive/Prescriptive reliability centered maintenance
    - Inspection and audit programs
    - Ongoing risk management evaluations
- Decommissioning: The system disposed of or land remediated.

The following are some of the best practices that are common to many of the LCM systems reviewed. These best practices are not specific to any one element (phase) of an LCM. Any of these best practices could support any one of the LCM elements (phases) described above. LCM systems that approach "management" beyond just maintenance or safety are better suited to BSEE's goals. The more comprehensive LCM systems include the following elements:

Asset integrity: The systematic implementation of activities, such as inspections and tests necessary to ensure that important equipment will be suitable for its intended application throughout its life. Specifically, work activities related to this element focus on (1) preventing a catastrophic release of a hazardous material or a sudden release of energy and (2) ensuring high availability (or dependability) of critical safety systems that prevent or mitigate the effects of these types of events. This element primarily involves (1) inspections, tests, preventive maintenance, predictive maintenance, and repair activities that are performed by maintenance and contractor personnel at operating facilities and (2) quality assurance processes, including procedures and training, that support these activities. Asset integrity element activities occur throughout the life cycle of the asset. Asset integrity documentation include:

- Reports and data from initial inspections, tests, and other activities to verify that equipment is fabricated and installed in accordance with design specifications and is ready for service at startup.
- Results from ongoing inspection tasks, performed by trained or certified personnel and are based on written procedures that conform to generally accepted standards that help ensure equipment remains fit for service.
- Controlled repairs and adjustments to equipment by trained personnel using appropriate written procedures and instructions.
- A system to control maintenance work, repair parts, and maintenance materials needed for the work to ensure equipment remains fit for service.

The primary objective of the asset integrity is to help ensure reliable performance of the equipment designed to contain, prevent, or mitigate the consequences of a hazardous incident. Although proper execution of work activities associated with this element requires a high level of human performance, the ultimate goal of asset integrity is reliable and predictable equipment operation. An effective asset integrity program depends on management ensuring:

- The equipment and systems are properly designed, fabricated, and installed
- The unit is operated within the design limits of the equipment
- Inspections are conducted by trained and qualified individuals using approved procedures and completed as scheduled
- Repair work conforms to design codes, engineering standards, and manufacturer's recommendations
- Appropriate actions are taken to address deficiencies, regardless of how they are discovered (Center for Chemical Process Safety, n.d.).

<u>Audit Regimes</u>: Audits are intended to evaluate whether or not an LCM system is performing as intended. An audit is a systematic, independent review to verify conformance with prescribed standards of care. A LCM system audit is the systematic review used to verify the suitability of the system and its effective, consistent implementation. Audits are important control mechanisms within the overall management of a LCM system. Additionally, audits can provide other benefits such as the identification of opportunities for improved operability, increased safety awareness, and greater confidence regarding compliance with regulatory requirements. Audits are conducted throughout the development and implementation of the LCM system. The nature and frequency of the audits are governed by factors such as the current life cycle stage of an offshore facility and the maturity or degree of implementation of the LCM system. Audits should occur during all life cycle stages, but primarily focus on the operational phase. While they can be scheduled on an as-needed

basis, audits of the LCM system should be typically conducted at some predetermined interval. For example, frequencies ranging from once per year to once every three years are common. Audits should be conducted by qualified personnel selected from a variety of sources, depending upon the scope, needs, and other aspects of the specific situation. Audits should typically be conducted by teams. Team members might be selected from the staff at the offshore facility being audited, from other company locations (e.g., from another offshore facility or from corporate staff functions). In some cases, it may be preferable to use someone from outside the company, for example, a consulting firm. A report of observations, findings, and recommendations for any needed improvements is typically prepared to document the results of an audit. Even though most audits will be primarily focused on operating offshore facilities, companies may choose to audit at different life cycle stages. These include research, development or design; during fabrication or inspection; or at such non-operational locations as a company corporate office or supplier. Recommendations for addressing any performance gaps identified by an audit are proposed, responsibilities and schedules for addressing the recommendations are assigned, and recommendations should be tracked to their resolution. Audit results should be trended over time to determine whether or not LCM system's performance is improving, with program adjustments made as necessary (Center for Chemical Process Safety, 2015).

Corrective and Preventive Action (CAPA) systems: The purpose of a CAPA system is to collect and analyze information, identify and investigate problems and take appropriate and effective corrective and preventive action to prevent their recurrence. CAPA should be viewed as an umbrella system that allows a company to assess its entire program. The scope of any corrective and preventive action system must include the verification or validation of corrective and preventive actions. Additional elements include communicating corrective and preventive action activities to those responsible, providing relevant information for management review and documenting those activities. These activities are essential in dealing effectively with problems, preventing their recurrence and preventing system or equipment failures. A CAPA system generally follows these steps:

- Documentation of the identified problem
- Assign appropriate personnel to investigate the problem and identify root causes
- Share finding of investigation with departments whose activities may be impacted by the investigation and corrective action implementation
- Identify root causes and corrective action
- Verify corrective action is implemented
- Document corrective action information in a database for future analysis
- Apply lessons learned from investigation and corrective actions to other similar activities
- Implement similar corrective actions to prevent the occurrence of similar conditions
- Verify implementation and effectiveness
- Document preventive action for entry into the database for analysis

- Maintain record corrective and preventive actions (Schnoll, 2001)

Hazard Identification and Risk Analysis (HIRA): HIRA is a collective term that encompasses all activities involved in identifying hazards and evaluating risk at facilities, throughout their life cycle, to make certain that risks to employees, the public, or the environment are consistently controlled within the organization's risk tolerance. These HIRA typically address three main risk questions to a level of detail commensurate with analysis objectives, life cycle stage, available information, and resources. The three main risk questions are:

- Hazard – What can go wrong?
- Consequences – How bad could it be?
- Likelihood – How often might it happen?

Tools available to accommodate varying analysis needs include:

- Simple hazard identification or qualitative risk analysis that include hazard and operability analysis, what-if/checklist analysis, and Failure Modes and Effects Analysis
- Risk analysis including Failure Modes, Effects, and Criticality Analysis (FMECA) and Layer of Protection Analysis
- Detailed quantitative risk analysis that include fault trees and event trees

HIRA encompasses the entire spectrum of risk analysis, from qualitative to quantitative. HIRA reviews may be performed at any stage in the life cycle, to include: conceptual design, preliminary design, detailed design, construction, ongoing operation, decommissioning, or demolition. In general, the earlier a hazard is identified (e.g., during conceptual design), the more cost-effectively it can be eliminated or managed. HIRA is typically performed by a team of qualified experts in the processes, the materials, and the work activities. Personnel who have formal training on risk analysis methods usually lead these teams, applying the selected analysis technique(s) with SMEs from engineering, operations, maintenance, and other disciplines as needed. The results of risk studies are normally kept for the life of the process and are communicated to those who may be affected (Center for Chemical Process Safety, 2015).

MOC procedures: MOC procedures help ensure changes to a process do not inadvertently introduce new hazards or unknowingly increase the risk of existing hazards. MOC procedures include a review and authorization process for evaluating proposed adjustments to facility design, operations, organization, or activities prior to implementation to make certain that no unforeseen new hazards are introduced and that the risk of existing hazards to employees, the public, or the environment is not unknowingly increased. MOC procedures also includes steps to help ensure that potentially affected personnel are notified of the change and that pertinent documents, such as procedures, process safety knowledge, and so forth, are kept up–to-date. MOC reviews are conventionally done for operating facilities, but are increasingly done throughout the process life cycle. MOC reviews start when qualified personnel determine that potentially adverse risk impacts could result from a change and suggest additional measures to manage risk. Based on the review, the change is either authorized for execution, amended or rejected. Often, final approval for implementing the change comes from another designated individual, independent of the review team. A wide variety of personnel is normally involved in making the change, notifying or training potentially affected employees, and updating documents affected by the change. Many organizations have written procedures detailing how MOC will be implemented. Such procedures apply to all work that is not determined to be a replacement in kind. The results of the review process are typically documented on a MOC review form. Once the change is approved, it can be implemented. Potentially affected personnel are either informed of the change or provided more detailed training, as necessary, prior to the startup of the change. Follow-on activities, such as updates to affected process safety information and to other LCM system elements are assessed. Higher risk situations usually dictate a greater need for formality and thoroughness in the implementation of a MOC protocol, for example, a detailed written program that specifies exactly how changes are identified, reviewed, and managed (Center for Chemical Process Safety, 2015).

Contractor Management: Industry often relies upon contractors for very specialized skills and sometimes to accomplish particularly hazardous tasks, often during periods of intense activity, such as maintenance turnarounds. Such considerations, coupled with the potential lack of familiarity that contractor personnel may have with facility hazards and operations, pose unique challenges for the safe utilization of contract services. Contractor management is a system of controls to ensure that contracted services support both safe facility operations and the company's process safety and personal safety performance goals. The use of contractors can place personnel who are unfamiliar with the facility's hazards and protective systems into locations where they could be affected by process hazards. Conversely, as a result of their work activities, the contractors may expose facility personnel to new hazards. Also, their activities on the site may unintentionally defeat or bypass facility safety controls. Thus, companies must recognize and address new challenges associated with using contractors. For example, training and oversight requirements will be different from those for direct-hire employees. Thus, companies need to carefully select contractors and apply prudent controls to manage their services. Contractor management begins well before the issuance of any service contract. Systems should be established for qualifying candidate firms based upon not only their technical capabilities, but also their safety programs and safety records. Orientation and training of contractor personnel should be accomplished before they begin work. Responsibilities for this training should be defined, with some training provided by the contract employer and some by the contracting company. The boundaries of authority and responsibilities should be clearly set for any contractor that works at the facility. Periodic monitoring of contractor safety performance and auditing of contractor management systems is required. At the end of each contract period, evaluation of a contractor's safety performance should help determine whether the particular contractor is retained or considered for future work. While some responsibilities for implementing the contractor management element are assigned to contractor personnel, many tasks are assigned to company staff at either the offshore facility or corporate level. Specific delegation of responsibilities between a contractor, corporate, and offshore facility personnel needs to be resolved prior to the start of a contractor company relationship. The anticipated work results of a contractor management program include:

- The creation of a list of pre-qualified candidate contract firms
- The selection of specific contractors with strong safety programs and good safety records
- The preparation of contract employers and their employees to safely provide their services based upon an understanding of relevant risks, offshore facility safety controls and procedures, and their personal safety responsibilities
- The safe delivery of the contracted services, with improved quality and productivity
- Appropriate documentation of the contractor screening and selection process, the contractor's safety performance during the performance of its services, and any other issues relevant to the evaluation of the contractor for potential selection for future services
- Outputs of the contractor management program can also be used to facilitate the performance of other elements; for example, contract workers must be trained to implement proper safe work practices and contract workers should be effectively integrated into the workforce involvement program

The scope of contracted services can encompass a broad spectrum, ranging from contracting with an individual to provide a very specialized service to contracting with a large firm (perhaps with many subcontractors) who will provide hundreds of workers with diverse skills for a major construction project or maintenance turnaround. A contracting firm could be on site for only a few hours and never to return, or could have a continuing presence at an offshore facility for decades. Some contractors will be directly exposed to the process and its hazards, while in other situations, such as new project construction adjacent to an operating unit, effective controls will be required to isolate the contractors from hazards. Finally, some contract service companies have a very stable workforce while others have a high rate of turnover. The contractor management program should be well-defined and flexible enough to handle this gamut of potential circumstances. The responsibilities and procedures for implementing these activities should be documented in a written program description with specific criteria for screening and selecting contract service providers (Center for Chemical Process Safety, 2015).

<u>Management Review and Continuous Improvement</u>: Management review is the routine evaluation of whether management systems are performing as intended and producing the desired results as efficiently as possible. It is the ongoing "due diligence" review by management that fills the gap between day-to-day work activities and periodic formal audits. The management review process provides regular checkups on the health of safety management systems in order to identify and correct any current or emerging deficiencies before they might be revealed by an audit or incident. The depth and frequency of each management review should be governed by factors such as the current life cycle stage of the offshore facility, the maturity or degree of implementation LCM system, and the level of management performing the review. Most of the management review effort will be focused on operating offshore facilities. While they can be scheduled on an as-needed

basis, management reviews are conducted at a predetermined interval. Frequencies ranging from monthly to annually are common, and they may be scheduled in conjunction with other regularly scheduled meetings, such as offshore facility safety committee meetings. Strictly speaking, every level of management should conduct periodic management reviews. The product of a management review is generally an internal memorandum summarizing the review, any deficiencies or inefficiencies noted, and recommendations for improvement or corrective action. The recommendations should be given deadlines and then assigned to specific individuals. All outputs of the management review are intended to facilitate the performance. In addition, the management reviews provide input that can be used to focus future audits. Management reviews are conducted with the same underlying intent as an audit, to evaluate the effectiveness of the implementation of an entire LCM system. Organizational changes, staff changes, new projects or standards, efficiency improvements, and any other anticipated challenges should be discussed so that management can proactively address these issues. The meeting minutes and documentation of each recommendation should be monitored over time, and more frequent reviews should be scheduled if persistent problems are evident (Center for Chemical Process Safety, 2015).

Training and Performance Assurance: A consistently high level of human performance is a critical aspect of any LCM system. Without an adequate training and performance assurance program, an offshore facility can have no confidence that LCM tasks will be consistently completed to minimum acceptable standards in accordance with accepted procedures. Training is defined as practical instruction in job and task requirements and methods. It may be provided in a classroom or workplace, and its objective is to enable workers to meet some minimum initial performance standards, to maintain their proficiency, or to qualify them for promotion to a more demanding position. Performance assurance is the means by which workers demonstrate that they have understood the training and can apply it in practical situations. Performance assurance is an ongoing process to ensure workers meet performance standards and to identify where additional training is required. Training takes place both in the workplace and the classroom, and it should be completed before a worker is allowed to work independently in a specific job position. Refresher training is provided on an ongoing basis thereafter as needed. Ideally, training is based on a needs analysis that defines the minimum acceptable KSAs required for a worker in a specific position. The analysis also includes any requirements imposed by regulations, codes, industry standards, or company policies. The training program should then be developed to bridge the gap between what is demanded of a qualified job applicant (e.g., basic reading and writing skills) and what is required to succeed in a specific job. The performance assurance system then tests the trained workers initially, and periodically thereafter, to demonstrate that they possess the required KSAs and are qualified to work independently. A training record should be provided for each worker showing that person's training needs, the dates on which initial training and any refresher training was satisfactorily completed, and a schedule of future training classes (Center for Chemical Process Safety, 2015).

The following are lessons learned and observations about the implementation of LCM Systems:

- LCM models that have failure reporting as a subordinate subset within the model's processes may be more useful than models where the LCM and failure reporting systems are separate processes. Stand alone failure reporting may create gaps in data collection, which affects the quality of analysis based on that data.
- Many regulatory bodies require operators to use other management systems (SMS, PMS, BMS, etc.) in conjunction with, or in lieu, of a LCM System. The incorporation of the LCM into another management systems is not inherently ill-advised and may be sufficient. However, as currently being applied by the regulators evaluated it is insufficient.
- In lieu of comprehensive LCM system regulations, most regulatory bodies use a patchwork system of regulations to address the elements of LCM Sytems. This type of approach has weaknesses. Chief among these weaknesses is inconsistency in requirements that creates gaps in the systems regulated and monitored, and gaps in data collection and analysis.
- The collection of data is a desirable goal for operators, owners, and regulators. Data management systems are essential to all elements of a LCM. However, if the data is not being analyzed and made actionable, the collection is burdensome at best and a liability at worst.
- LCM systems that have integrated decision support systems such as manual or computer-based tools that assist in some decision-making activity are preferable.
- LCM that have data collection and analysis processes for evaluating data from various sources that are analyzed to form a finding or conclusion are essential.
- LCM that have measures of performance systems for tracking performance expressed as frequency or other distinctly quantifiable performance features are critical to LCM management.
- Formal management systems can support LCM systems, but they should not be used to supplant a distinct and fully formalized LCM systems.
- LCM systems that add value beyond improved safety (i.e., operational improvements in cost, downtime, efficiency, effectiveness) will be more readily adopted by operators.
- Formats for collecting data from LCM systems should be prescriptive to ensure the data used for analysis is consistent and comparable.
- LCM systems that are supported by software platforms are preferable.
- LCM systems that have failure reporting systematically integrated into the LCM function are more effective. By incorporating failure reporting into the LCM system there is a reduction of data gaps and a more robust analysis system in place.
- LCM systems applied to multiple operators must use a common lexicon.
- Significant improvement in LCM systems could be achieved with planning, training, clear performance standards for testing, and maintenance regimes.
- The industry is not effectively sharing good and best practice.
- LCM systems need key indicators of performance available at the most senior management levels to inform decision-making and to focus resources.

5.3 Role of Industry

Industry's role within the construct of the LCM process is to identify the regulatory requirements as set by the government agency responsible for managing and enforcing the laws associated with a particular program. Industry must determine the requirements within regulations that apply to their organization and structure their LCM system (if required) to meet or exceed the regulations. Though none of the government agencies reviewed for this project specifically require industry to develop an LCM system by name, imbedded in the regulatory requirements in some countries, are requirements for organizations to establish safety and environmental tracking and reporting systems that effectively lead to the development of an LCM system.

For example, in New Zealand, regulations are in place that prescribe the development of a SMS under the Health, Safety and Environmental laws. Organizations seeking permission to conduct business must develop an SMS and most organizations will be required by the regulations to develop a Safety Case to specifically describe how the organization will conduct business, describe safety measures to protect employees and the environment, and describe how the operation will be maintained from start-up to decommissioning or closure. Each of these specific requirements must be clearly described in the Safety Case, which must be approved by the government regulatory authority prior to beginning operations, and made available for audit and inspection as defined in the regulations.

This same basic process and concept is applicable to the LCM system and requirements in the U.K. and Norway where Safety Cases are required. There may be subtle differences in the actual regulatory language, but conceptually the programs are similar. The U.K. HSE and Norway's PSA rely heavily on industry input when developing specific regulations and guidelines for their Safety Case approaches. For example, the U.K. HSE sought to address issues particular to O&G operations on mature fields, as several industry members operated on the U.K. Continental Shelf (UKCS) with equipment that approached or exceeded life cycle expectancy under their initial LCM-based programs. The U.K. HSE, in response, then developed the KP3 and KP4 programs to adapt to the unique concerns of operators under its regulatory jurisdiction, while still upholding the goals of its Safety Case approach.

In most cases, industry organizations rely heavily on ISO and API standards, recommendations, and best practices, in addition to IADC guidelines, when developing LCM systems. In some cases, industry standards are incorporated by reference in regulatory frame work, and industry must then apply those standards when developing an LCM system if required. At a minimum, in the case of the U.K., Norway and New Zealand, if these standards are incorporated by reference in the regulatory framework, then the specific standards must be addressed when developing their Safety Case. In the U.S., where LCM systems are not required, industry relies heavily on the ISO and API standards and best practices and IADC guidelines to develop programs that address safe working environments for employees and attempt to meet or exceed environmental safety practices.

Another important role industry plays is providing feedback and recommendations to regulators. Feedback is particularly important as regulatory changes are proposed, training requirements change, reporting requirements change, guidelines are adjusted due to technological advancements, how lessons learned from accidents or incidents impact new guidelines or updates to current or proposed regulations, and economic fluctuations. Some industry groups have developed user groups or working groups within their industry to collaborate on issues specific to their operations. These user groups provide a unified voice to provide regulators feedback on industry related issues. Some user groups include government representatives and work directly with regulators to address proposed or recommended changes to regulations, identify training needs, collaborate on best practices and provide input on the development of new or current standards or guidelines.

For example, Oil and Gas UK is a not-for-profit organization where organizations working within the O&G industry can become members and work together with regulators to address issues that are relevant to the UKCS and the offshore O&G industry. This consortium provides a direct link to regulatory organizations and as a 500 plus member group, a powerful voice.

As mentioned earlier, the PSA in Norway also engages with industry extensively through a similar process in its Regulatory Forum. This Forum provides a space for representatives of the industry to address current issues with PSA representatives, discuss goals, and ultimately establish an agreement on the direction of new regulations and guidelines through mutual cooperation.

Another important role of industry is to provide data to regulators. In order for the data to be useful however, it must be accurate. The importance of factual data is critical and very valuable to regulators for identifying trends. These trends can lead to necessary regulatory updates; the identification of gaps in training; the identification of safety, security and risk issues; and potentially provide an overall economic state of the industry. However, industry has been resistant to supplying some data, particularly data that is not required by regulations, data that may be used for enforcement purposes or data that identifies possible safety issues or violations.

Accurate incident reporting is an important part of the data collection process as well. In all cases, each regulatory agency researched for this project has incident reporting requirements included in their regulations. Industry is required to submit incident reports if they involve serious injury or loss of life, incidents involving major structural damage, and incidents involving damage to the environment. Reporting requirements vary depending on the nature of the incident and its severity. The following are examples of required reports from the PHMSA. PHMSA regulations require industry organizations to make reports on any leak where conditions exist that present a danger to life or property. There are three required reports: 1) within the first three hours of an incident, operators must report the incident to the National Response Center (NRC); 2) an incident report must be submitted to PHMSA within 30 days; and 3) operators are required to submit an annual report by mid-March each year.

The NRC employs a somewhat different approach with its Licensee Event Report (LER) program (see Task 3 Report). While it has separate incident and emergency reporting programs, LERs specifically correspond to non-emergency incidents where threats to human safety could have been realized. LER reports serve as retrospective summaries and analyses of events, not immediate reports to the NRC as a situation unfolds.

The primary role of industry is to develop programs, processes and systems as prescribed in applicable regulatory requirements. These programs, processes and systems must provide a framework for a safe working environment for employees and ensure operations are conducted to prevent adverse environmental impact. Significant deviation from regulatory requirements in the form of accidents or incidents must be reported and it is industry's responsibility to ensure required reports are accurate and delivered within the prescribed regulatory timelines.

5.4 Statutory and Regulatory Elements

Clear definitions provide companies an understanding of what information needs to be collected, gathered, and submitted. What happens to the data also needs to be determined and understood before any data is collected. Continued effective reporting requires BSEE to provide the industry with feedback and useful analytics derived from the data provided. Industry wants validation of the submission of data by seeing value from that submission.

A full and robust LCM requires:

- Standardization
- Strong management
- Strong reporting
- Approval and process mechanisms
- Review and analysis
- Issues of what the right information might be

Another area of future concern is how to address critical equipment when the equipment lasts longer than expected. An LCM system should be flexible and adaptable enough to capture additional information that might be of use later.

A key component is responsiveness of data. Industry is concerned about the benefit to and outcome of providing information to regulators and more specifically, the time it takes to receive feedback on the information provided. Responsive analysis of the data provides the industry the reason and rationale for the continued provision of data to BSEE. If there is a long temporal gap between data collection and data utilization, then the value to the industry is diminished. If there are no actionable increases in safety, then there may be little value provided to the industry from the data provided.

In addition to the definitions, clear and understood penalties will aid in the understanding of the requirements as well as improve compliance with a regulated system.

5.5 Effectiveness

Determining the effectiveness of the LCM systems surveyed in this study presents a challenge since the LCM systems differ widely in their goals and objectives. For example, the USCG uses a five-year average for deaths and injuries, oil spills and chemical discharges to monitor the effectiveness of its programs. The FHWA monitors trends in the increase/decrease of maintenance, vehicle accidents, driver and passenger injuries or death, destruction of properties, and economic impacts due to loss of use to assess effectiveness.

Some of the LCM systems examined encourage the users to measure effectiveness in terms of improved process performance, increasing operational efficiency and effectiveness, minimizing risk, improving safety, improving compliance, or reducing costs. But these systems do not define standards by which to benchmark measurements of effectiveness. Standards or guidelines developed by the ISO, API and the IADC fall into this category.

In the international arena, determining effectiveness of specific LCM systems was very difficult. There are several reasons for this difficulty. For example, in the U.K. and New Zealand regulatory requirements for organizations wishing to conduct business in the O&G industry require the company to develop and seek government approval of a Safety Case. The Safety Case regulations do not stipulate requirements to track the effectiveness of individual organizations' LCM systems. Since there are no stipulations to track LCM systems, there is no data available to determine agency or company LCM effectiveness directly. Anecdotally, it can be assumed that larger organizations have used LCM systems effectively as they typically have the personnel and resources to effectively manage these programs, whereas smaller companies may or may not employ LCM systems due to resource constraints, financial reasons, or a business philosophy of "run it until it fails and replace it."

The one overarching theme of all the models is the goal of reducing the loss of human life, injuries, and incidents of hazardous materials spills that result in environmental damage. As such, the clear linkage between LCM systems and failure reporting is essential. Failure reporting information is used to feed the LCM process so organizations can track trends and identify potential areas for improvement.

One observation regarding effectiveness is that clear and open communications between regulators and industry is critical for program effectiveness. When regulatory entities provide industry with the opportunity to provide feedback about regulations, policy decisions and process, industry is more willing to trust and work with regulators to establish effective and functional regulations. For example, in the U.K., Oil and Gas UK serves as an effective consortium of more than 500 industry and government representatives that work together to identify potential regulatory updates or changes and collaborate on lessons learned on issues including safety, security, supply chain, training, and contractor and subcontractor relations issues. Similarly, the PSA in Norway chairs a Regulatory Forum to meet and discuss current issues and regulatory development with industry representatives.

Some LCM systems are being used in unique ways to assess environmental performance improvement opportunities, such as determining energy efficiency and resource productivity, evaluating technology trends to assist in business planning, assessing new technology for better environmental performance opportunities, and tracking regulatory compliance and support legal issues. LCM systems are also being used to examine existing practices and technologies to identify opportunities to maximize economy and environmental stability. Though economics is not the primary focus of an LCM system, it is clear that economic improvement can be realized through better efficiency and resource productivity. LCM systems are also being used to measure tangible improvements such as energy consumption, health and safety, and environmental impact.

The one definitive statement that can be made is that the more comprehensive an LCM system, the greater the potential for its effectiveness. LCM systems that include asset integrity, audit regimes, corrective and preventive action, hazard identification and risk analysis, contractor management, management review and continuous improvement, and training and performance assurance elements are the most effective.

5.6 Liability

All the organizations evaluated for this study may bear the potential effects of legal liabilities associated with the implementation of a LCM system. What distinguishes them is the degree to which they may be subject to those legal burdens. Operators of offshore facilities may be exposed to adverse legal action from a countless number of organizations or individuals following a significant incident. Any LCM system in use will be the subject of a high degree of scrutiny from a host of potential actors. Implementing an industry organization standard from ISO, API, IADC, or others that provide LCM models would show a good faith effort in achieving a higher standard of safety. Standards Organizations may also find themselves the target of unwelcomed litigation, but the likelihood is significantly less. The good news for any of these organizations is that a properly implemented, or designed, LCM system could be an important asset rather than a liability.

For example, offshore operators that implement an LCM system may realize substantial mitigation of potential liabilities because LCM systems provide offshore operators with the ability to make proactive and methodical management decisions about critical and potentially hazardous operations. Therefore, LCM systems may have the effect of limiting organizational liability and increasing compliance with legal requirements. LCM systems provide operators with a degree of defense because having a system in place demonstrates due diligence. It may be easier for operators to diminish their culpability because they can prove that they use the systematic decision methodologies and documentation procedures provided by an LCM system. LCM systems are by no means a panacea for all the potential liabilities an offshore operator will face. However, the ability to prove that important decisions are comprehensively evaluated before they are made could be invaluable if there is a substantial incident.

Still, there is a glaring potential gap that could render useless the potential liability limiting effects of an LCM system. This potential gap lies in the relationship between operators and subcontractors in deep water drilling. If an operator institutes a comprehensive LCM system that is supported by a strong safety culture but they use a subcontractor who does not participate in or is not actively monitored by that LCM system, the operators may expose themselves. That is why contractor management has been highlighted as a best practice in this report.

In addition to legal liabilities, offshore operators are subject to substantial financial liability. Because there are no insurance requirements under Oil Pollution Action 90, many large drilling firms are self-insured. This practice has come under heavy criticism, and has sparked much debate about establishing a mandatory system of insurance for offshore drilling operations. However, mandating insurance may have unintended consequences. For example, it is possible that a company that has purchased insurance may to some degree be de-incentivized to maintain the highest standards of safety because it is now financially covered in the case of an oil spill. To overcome this situation, an insurer might institute a system of risk-based pricing so that firms with higher risk exposures pay higher rates, thereby creating an incentive to reduce risk. Additionally, insurers may increase the level of their oversight. Insurers will very likely focus on assessing the safety cultures of operators. The adoption of a strong safety culture could become one of the key benchmarks by which liability caps are set. In such a case, offshore operators who have implemented effective LCM systems will most likely realize substantial financial benefits from reduced insurance rates. On the other hand, if market forces keep the liability caps low, insurer's monitoring incentive may not be very strong. In this case, there would fewer incentives for offshore operators to voluntarily adopt LCM systems. Without the pressure of keeping insurance rates low, there will be operators who will not perceive the benefits of LCM systems and choose not to implement such systems in an effort to keep down cost. In this scenario, the government is best suited to encourage, or if need be mandate, the implementation of LCM systems (Cohen, Gottlieb, Linn, & Richardson, 2011).

Other countries have implemented the IADC's guidelines for LCM as part of their Safety Case approach to regulation. Given the legal structure of the U.S., BSEE would be held as potentially negligent if this approach were selected. The liability issues that confront BSEE are different than those posed to the regulated industry. If BSEE mandates an LCM system, liability would shift from the industry to BSEE for the effectiveness and compliance with the regulations. If a company is in compliance with the regulations, but an event still occurs, then BSEE's regulations could be viewed as an issue.

BSEE would also face a liability issue if data from LCM systems are collected. If the data is too transparent, then industry organizations might file suit, particularly if a Freedom of Information Act is requested and company proprietary data are released. Additionally, an excessive data request could result in an undue burden to the company and to the industry, particularly if the industry does not perceive the benefit of compliance with data requests.

For an LCM system, liability issues should not be a main issue for the industry. An LCM system should be implemented to take advantage of Best Practices, many of which are already adopted within the industry. Since an LCM system should be more focused on preventative maintenance, the largest areas of liability from a regulatory LCM mandate are the data collection and data use.

5.7 Data

Effective data management plays an important role in improving the performance of any LCM system. Collecting, analyzing, interpreting, and acting on data for specific performance measures allows LCM managers to identify where systems are falling short, to make corrective adjustments, and to track outcomes. The best decisions are evidence-based and data-driven. LCM systems that control hazardous processes or critical equipment must have access to accurate data to improve the organization's performance. As a result, data quality is an essential requirement for any performance improvement initiative. The following are some key points about effective data management for LCM systems:

- The data collection process should ensure data being collected are useful, reliable, and resource-efficient
- The data collection will be influenced by the areas needing improvement
- The data being collected should have quality measurements
- A standardized data collection procedure is critical for consistency and data quality
- Data collection systems that inform Original Equipment Manufacturer (OEM) providers are desirable

The collection of relevant and accurate data is one of the most important aspects in an effective LCM system. Most of the regulatory agencies surveyed dictate a format for reporting to ensure some level of consistency. However, the level of detail collected and scope of definitions for the reporting requirements vary widely between agencies. Many of the agencies and organizations studied placed the burden of collecting data on the offshore owner/operator. This more decentralized model of data collection increases the amount of data that can be gathered, while reducing the cost to regulatory agencies like BSEE. For example, FHWA relies on individual state's DOT to gather necessary data for its PMS, BMS, and SMS. This is the model that most of the European regulatory agencies follow. One significant exception is the USCG, which places the burden of data collection and analysis entirely on USCG employees.

One issue BSEE will have to meet head-on in advance of imposing any LCM system model on the offshore industry is the potential availability of data collected by LCM systems. BSEE will have to artfully balance the need to collect and preserve the data without unintentionally disclosing data that could be harmful to those who are providing the data, with BSEE's desire to use the data to communicate risk and educate the industry and the public. Very early on, BSEE will need to develop clear processes and rules for handling such data to strike that balance. Another issue that must be addressed before implementation is determining what data from an LCM system need to be collected. Indiscriminate collection of data could have potential adverse effects. If too much data is required, it will impose a significant resource burden on those who have to provide the data and also on BSEE, who will have to analyze the data. Additionally, the collection of superfluous data may create a liability for both the reporter and BSEE. The collection of any data creates the expectation that the data will be analyzed and acted on, even if there are minimal benefits to doing so.

5.8 Application to BSEE

BSEE should not consider these LCM systems reviewed for this study as an "off the shelf solution." As such, BSEE will be faced with a philosophical fork in the conceptual road. One path takes BSEE in the direction of using a combination of existing regulatory frameworks to build its own framework. The other path has BSEE going in the direction of building a completely new, and as yet undefined, regulatory framework that is unique to BSEE. Each path has relative advantages and disadvantages. The first path involves less risk, requires fewer resources to design and implement, and will probably take less time. However, it may be less effective and comprehensive. The second path will involve less risk, will require extensive resources and will undoubtedly take longer than the other path. However, this path also offers the least restrictions and may afford the best opportunity for a comprehensive framework. The discussion that follows will explore the first path, and examine what existing conceptual frameworks are available and how they apply to BSEE. The second path will be explored in a later report.

Even the standards best aligned with the offshore industry (i.e., ISO, API, and IADC), will require some augmentation to meet the goals of an inclusive regulatory regime. For example, the API and ISO lack an industry-wide failure reporting data repository, and there are no mechanisms for user/operators, manufacturers or associated subcontractors to garner lessons learned. API standards for LCM lack any control mechanism, so BSEE would have to supplement these standards with additional metrics and reporting requirements. Additionally, ISO life cycle standard's definition of "quality" is somewhat elusive. Subsequently, the LCM systems may merely measure whether processes are being followed, not whether processes are achieving acceptable results. ISO accreditation may be an indicator of quality, but it is not a guarantee. Heavy oversight will be required because there can be no assumption that ISO LCM certification significantly lowers risk. The IADC standards are very comprehensive in dealing with Health, Safety, and Environment cases for drilling contractors. The IADC standards allow flexibility in tailoring the Health, Safety, and Environment cases for specific operations of varying scales, and in doing so, promote efficiency and avoid redundancy and unnecessary paperwork. However, the IADC standards lack satisfactory measurements of safety or reliability.

Additionally, the extensive adoption of ISO, API, and IADC standards presents political realities that could be a potential minefield for BSEE. Specifically, it could be argued that the ISO, API and IADC standards have already been proven inadequate to regulate offshore drilling. The basis of this argument is rooted in the fact that: (1) prior to the Deepwater Horizon oil spill, BP met, or in many cases may have exceeded, all the applicable API and IADC standards in place at the time of the oil spill, and (2) at the time of the Deepwater Horizon oil spill BP was ISO 9001:2008 and ISO 14001:2004 certified and had been so since the year 2000. Many investigations in the wake of the Deepwater Horizon oil spill criticized the Outer Continental Shelf Lands Act for having too few standards to assure protection of health, safety, and the environment. Additionally, BSEE's predecessor, Minerals Management Service, was almost universally criticized for a regulatory approach that many claimed relied too heavily on API and IADC standards.

Looking to other domestic regulatory agencies for LCM models to emulate may offer some best practices, but nothing resembling a full-blown regulatory model for LCM systems. Culturally and jurisdictionally, BSEE and the USCG have the most in common. There is much that BSEE could learn from the USCG; unfortunately, the USCG does not have a regulatory model that can be readily adopted as a LCM system model. As noted, the USCG's enforcement of Title 46 is in fact a LCM system that is already applicable to the OCS. More specifically, the model provided by 46 CFR Subchapter Q could serve as a framework for a regulatory system that gives BSEE greater control over critical systems being installed on offshore installations. This framework could allow BSEE to establish their own standards or incorporate by reference widely accepted industry standards and best practices. Likewise, BSEE could consider using their existing regulations to develop "USCG-like" maintenance requirements. In 30 CFR 250.10(a)(2), 30 CFR 250.130(b), and 30 CFR 250.401(e), BSEE could develop regulations that are modeled after USCG regulations for lifesaving, firefighting, pollution prevention, engineering, electrical and structural systems. The USCG does have some internal LCM policies that may be instructive; chief among them is Commandant Instruction M9000.6, Naval Engineering Manual. In this policy, the USCG outlines its application of RCM methodology for the vessels it operates. However, the USCG has no single methodology or policy that speaks to the agency-wide application of LCM. Instead, the USCG uses multiple policies that address the various aspects of LCM. In truth BSEE would have to build a model from the pieces of authorities, processes, and reporting systems that the USCG has somewhat haphazardly developed over the last 80 years.

The other Federal regulatory agencies examined for this report have some useful structures, but these structures do not form a coherent LCM model that BSEE could easily modify for their use. For example, PHMSA, NRC, FHWA and the Department of Defense all address LCM systems but describe the elements and phases of the LMC system to focus narrowly on their regulatory responsibilities. For example, some of the LCM systems begin with conception and design, while other LCM system models do not start until procurement or construction. Also, there is an inconsistency in the language to describe the elements or phases of the LCM systems. Therefore, there is no single Federal model that would constitute a workable LCM system model that would fit BSEE's needs, leaving BSEE to single out the useful elements to create a new conceptual model that ties these different elements into a holistic and workable model.

There are some European regulatory agencies that offer more comprehensive LCM models that could be explored more in–depth, but even these models would need to be modified to accommodate BSEE's existing jurisdictional boundaries. The European approaches to regulating LCM systems in the offshore industry tend to be less prescriptive and are industry led and risk-based. The U.K. HSE's KP4 broader scope program looks beyond strictly material safety to include leadership and preparedness, audits, and data management, and it holds out promise as a model. The U.K. HSE and PSA's LCM plans and Failure Reporting Systems are thorough and comprehensive. The U.K. HSE and PSA's models also allow flexibility for the operators under a LCM framework that allow operators to tailor the framework to the operator's needs. The Oil and Gas UK consortium could be seen as a model organization that provides an open dialog for participating entities to keep all offshore O&G issues and best practices at the forefront of the discussion. However, as discussed previously, these types of models may not be appropriate for the domestic political climate in which BSEE must operate because they are less prescriptive and are industry-led and risk-based.

Our review of these entities has led us to conclude that a perfect comparable LCM system was not identified to present a fully developed conceptual framework that is suitable for BSEE's challenges. However, there are opportunities for BSEE to use aspects or elements of these other models to develop regulatory frameworks of its own. Choosing to build on these existing regulatory frameworks will probably involve less risk and take fewer resources to design and implement and possibly take less time. The price for choosing such an approach, however, is the resulting model may be less than optimal.

6. Recommendations

The following recommendations are based on information collected during the research of the above organizations. Our review also shows that many offshore petrochemical industry participants are currently engaged in LCM and have robust systems in place. ABS Consulting's review shows that regulatory approaches can be displayed on a spectrum of less to more industry engagement as shown in Figure 8, with "prescriptive" regulations being characterized by command and control regulations, heavy inspection schedules and onerous reporting requirements for industry. These may or may not align with existing industry practices. Examples of this include PHMSA's regulation of pipeline transportation companies. In contrast, systems based on industry involvement and consensus standards are generally performance-based and tend to allow industry more flexibility in defining the compliant system that would meet both their operational needs and the safety and data needs of the Government. In terms of the LCM systems, these are deemed "Industry Involved (Industry Standards)" and are exemplified by the IADC, API or ISO LCM programs. A "Hybrid" LCM approach would be a blend of both prescriptive and industry involved LCM models.

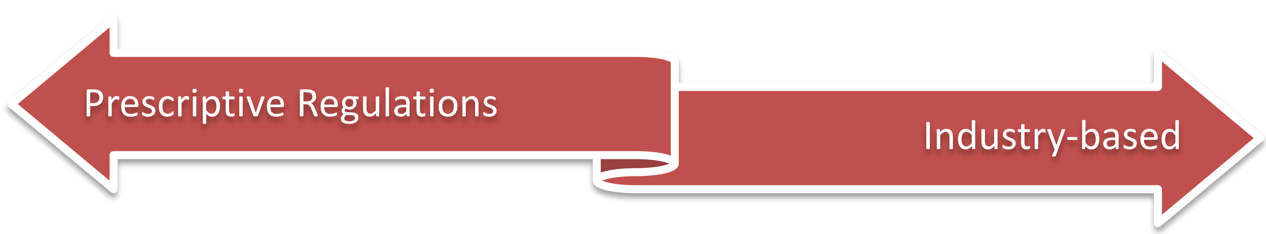

Figure 8: Regulatory Spectrum

Feasibility is a key consideration in developing recommendations that may actually lead to successful implementation. Defining a regulatory framework that meets the needs of the government yet provides enough flexibility to accept industry input is a significant policy challenge but one that readily eases implementation and industry acceptance. Since much of industry has already implemented a LCM system as good business practice, BSEE's goal should be to develop a regulatory regime that is robust enough to ensure the safety of employees and the environment while being flexible enough to allow industry to continue with their best practices. In this way, BSEE can avoid creating redundant or onerous resource and financial burdens on industry.

Industry will likely seek to have input based on current business practices and lessons learned to help mold any new regulations into those that make sense, enhance safety and performance and are relatively easy to implement. Industry will also desire an effective feedback mechanism that will provide them shared information and results based on any data they are required to report.

ISO and API standards are already in use by industry, thus any implementation of an LCM program should begin with a consideration of current industry standards and best practices. BSEE's approach to incorporating API Q2 and Q3 will provide a basis for development of a system, and with additional regulatory guidelines, industry can develop their programs within that framework. By incorporating these standards by reference, it is likely that BSEE can improve regulatory acceptance as a first step.

6.1 Definitions

A key finding from industry is that if BSEE were to implement any sort of LCM system, regardless of incorporation of standards or the development of a new standard, BSEE needs to set clear and understandable definitions and guidelines.

One observation that has been made repeatedly throughout this process is how vital definitions are. In the review, agencies with clear and comprehensible definitions tended to have better compliance by their industry since the program was better understood. Industry repeatedly and clearly identified definitions to be a key issue for them. Industry feedback requested that definitions be: clear, uniform, plain English, understandable, comprehensible, and specific.

Identifying the pieces of equipment whose failure could result in a catastrophic event is essential to a risk-based LCM approach. This could ultimately have impacts beyond maintenance and failures, to design criteria and minimum standards of acceptable conditions. It is critical for LCM systems to clearly define what needs to be part of an LCM system and what should be recorded and reported. Examples of this clear definition approach include the USCG which provides a list of components to be checked as part of a maintenance requirement, and PHMSA which provides broader types of systems to be incorporated into a LCM system.

Therefore, we recommend that any LCM requirements developed by BSEE place a priority on developing clear and understandable definitions of what constitutes critical systems. This recommendation is applicable to LCM in defining clear and concrete reporting thresholds. In addition to what systems are to be reported and what qualifies as a reportable event, who receives the report is also critical. If the piece of equipment requires excessive maintenance or fails in a way which could affect safety, this should trigger an investigation. The OEM should also be notified so that they are alerted of the possible need for design improvements.

In mandating an LCM system, BSEE may not be concerned about the specific maintenance levels of all the components on a facility. Nor would BSEE need to care about the efficiency or improvements in operations that an operator would be looking for in an LCM system. These are typically the reasons industry develops and implements their own LCM systems. The regulatory authority would be more concerned about the maintenance and performance of critical equipment and systems, which if not properly maintained, might result in an incident should a failure occur. Definitions of what criteria make systems critical, such as safety related functions, will be key in reducing the documentation requirements of the operator. Industry recommends that BSEE define what their "Top 10" critical equipment or systems concerns are, and focus on the collection of data for those items specifically. This way, BSEE avoids placing burdens on industry for the collection and reporting of all data, since much of the data may not be of value.

Due to varying definitions already in place in the industry, standardization, guidance and clear definitions is a necessary step. OEMs, industry members, industry support, and industry organizations' definitions of criticality, critical equipment and critical systems have wide variance.

Given the example of a gas detection system, there will be many sensors and different configurations that may be unique to each OCS unit. Each company may set a different level and different determination of whether a sensor, a group of sensors, or the entire gas detection system is critical. Ideally, a LCM system will allow for that flexibility and variation between facilities.

6.2 Regulatory Approaches

ABS Consulting has identified three approaches that BSEE can take in implementing regulations for an LCM system: prescriptive, industry-involved, or a hybrid approach. Given the multiple options of implementing regulations mandating an LCM system, BSEE would need to define and identify what their role will be, whether as an auditing authority or as an inspecting authority. Regardless of whether BSEE chooses to audit or inspect, the level of audit or inspection must be determined and specified. BSEE would need to consider whether remote auditing of outputs and dashboards with a review of the LCM software and records be sufficient or would an on-board inspector and collection of data still be required.

6.2.1 Regulatory Option 1: Prescriptive LCM Option

One regulatory option BSEE could explore would be the implementation of a prescriptive LCM program. BSEE could develop very prescriptive regulations that address all the safety and risk required elements needed to regulate industry and more specifically the requirement for an LCM program. These requirements could include specific systems to be included in an LCM system, mandatory recordkeeping and reporting requirements (to be prescribed by regulation), mandatory enforcement inspections and verification of the LCM program and processes to ensure the program is being managed and operating as required. This could be backed by strict penalties for noncompliance to ensure the LCM program requirements are adhered to. This LCM program should be developed using a safety and risk based approach that is specifically mandated in the regulations.

A key issue with a prescriptive approach is that the regulatory guidance may become too specific. With the diversity of the companies in the industry and the large variety of systems and equipment, finding a one-size fits all prescriptive approach may have a high likelihood of failure. Many companies already have implemented custom LCM systems with varying levels of sophistication and detail tailored to suit their operational needs. This was typically done for business purposes to enhance production and better manage maintenance costs. Data outputs and inputs may be unique to the company and may not be comparable to another software solution.

Given that several members of the industry have already invested significant time and resources for custom-built asset management software solutions (which may incorporate LCM and Failure Reporting along with maintenance planning and requirements like Safety and Environmental Management Systems [SEMS]), the O&G industry may present strong pushback on an approach they deem to be too prescriptive, particularly if it is seen to be duplicative of current systems in use by industry.

The USCG's maintenance and inspection requirements could be a useful prescriptive framework for BSEE to consider adopting. The USCG does not have a specific LCM system as part of their regulations; however, the USCG does maintain a list of specific critical equipment as part of their Subchapter Q and operators are expected to maintain their vessels and equipment properly. This list is a culmination of decades of accident history, which points to a key weakness in this approach: the list is not predictive, but reactive. Much of Subchapter Q is predicated on maintaining a certain standard for critical equipment and sets an interval period for inspection. For example, BSEE should consider developing maintenance requirements in 30 CFR 250.10(a)(2) and 30 CFR 250.130(b), 30 CFR 250.401(e) and any other sections of BSEE regulations for particular components that have been associated with incidents or failures that have impacted health, safety, property, and the environment. This would be akin to the USCG's mandated maintenance requirements for components associated with lifesaving, firefighting, pollution prevention, engineering, electrical and structural systems.

6.2.2 Regulatory Option 2: Industry-based LCM Option

The industry-involved approach can take many directions, whether by safety case, industry self-regulation by industry standards, or by shifting requirements to the OEM.

6.2.2.1 Safety Case

An industry-based policy option available to BSEE is implementing a highly industry-involved LCM. BSEE could use the structures and processes similar to the U.K. HSE, Norway, New Zealand and other international O&G regulators. These countries require a "Safety Case" for all installations operating in their territorial waters and on the designated areas of their countries continental shelf. It is generally the owner or operator's responsibility to submit the safety case as the design matures. For proposed new production installations, operators must send notification at the early design stage. The safety case must demonstrate that the owner or operator has arrangements in place that are capable of complying with all regulatory requirements. The safety case provides a comprehensive document that can be used as a check by both the owner or operators and BSEE that the acceptable risk control measures and health and management systems are in place and will operate as required. Identifying the required elements of the safety case would be critical for BSEE as it applies to LCM.

Under a Safety Case regime, the company would outline what their activity will be, how to implement a program, and how the company will operate. Regulations would provide the structure and guidelines for what should be included in the program and how the facility can meet or exceed these requirements.

This approach would shift the role of the regulator from an inspection body to an auditing body. Many regulators allow industry to create and implement their internal program, with the regulating agency acting as a validator or auditor of the plan.

BSEE should endeavor to ensure (when applicable) that required LCM reporting does not have punitive consequences for industry participants when submitting required reports. In this regard a review of the Oil and Gas UK's Industry Mutual Hold Harmless (IMHH) agreement may be useful to help develop a regulatory or legal structure which places limits on industry participant liability. Inspections and auditing of the LCM program must also be specifically addressed in the LCM section of the safety case. Communications are a critical element as well. The LCM portion of the safety case should include reporting requirements (i.e., paperwork, data uploads, telephone notifications) that are easy and quick to submit.

While this approach reduces the operational load of the regulator, it also limits the agency's ability to control and affect change throughout the industry. BSEE would need to develop the common standards, but would provide the industry latitude in the implementation of a process to meet those minimum common standards.

6.2.2.2 Industry Standards

Industry standards are another type of an industry-led approach suggested for BSEE's consideration. Industry organizations like IADC and API set standards like the API Q2 and Q3 and the standards regarding the maintenance of various types of equipment and systems. These could serve as the basis of a standardized, industry-wide LCM program that BSEE could mandate.

ISO and API standards are already in use in much of the industry, thus the assessment and understanding of industry standards will be a key first step. In order to use industry standards to establish LCM across the industry, BSEE must also secure industry participation. By incorporating these standards by reference into its regulations, BSEE can facilitate regulatory compliance among industry. BSEE's approach to incorporating API Q2 and 18 LCM would provide a basis and starting point for development of a system, and with additional regulatory guidelines, the industry can gauge how well their existing programs align with the minimum requirements as defined by BSEE.

If BSEE incorporates these standards with a set of standardized data requirements, then BSEE can be able to do applicable data pulls from industry as necessary.

6.2.2.3 OEM Regulation

BSEE may choose to look to the OEMs as the basis for establishing LCM requirements. Many operators in the industry already report failure information back to the OEMs or OEMs capture the information on their own products. BSEE could require the OEMs provide LCM data and could combine and synthesize the data and publish it for industry-wide dissemination. Product related issues related to reliability, quality or maintenance issues could be reported to the OEMs from industry. While possible, this approach is likely to provide limited benefits for an LCM system as much of the maintenance and repair issues would be out of the OEM's control.

6.2.2.4 Third Party Oversight

A final industry approach would be to use independent third parties to ensure industry has successfully implemented an LCM program. Examples of this approach include Classification Societies which establish rules and standards for the proper maintenance of ships and rigs. Class societies have reporting requirements for their members, inclusive of the maintenance plans and requirements. Classification Societies are representative of the industry, but act as a semi-regulatory body of the industry.

6.2.3 Regulatory Option 3: Hybrid LCM Option

A third regulatory approach available to BSEE is a hybrid LCM option. Many of the international regulatory agencies reviewed in this research use a flexible yet somewhat prescriptive regulatory process. The critical element of developing a functional hybrid LCM regulatory regime will be to identify the specific critical components of an LCM program. Under the hybrid approach, BSEE could require industry to identify the critical systems subject to the LCM for their facilities. BSEE could then specify the minimum elements of an LCM system including recordkeeping and documentation requirements. Once operations at a facility are underway, BSEE could include periodic audits of the LCM program by reviewing records and documentation. This would ensure industry organizations are following and adhering to their developed LCM program. In addition, it would be beneficial if industry provided LCM and failure data to the OEMs so that reliability enhancements could be implemented.

Communication and cooperation are critical for a program of this nature to be effective. There must be an effective feedback loop with exchange of information for required data input requirements. One way to ensure industry and BSEE communicate openly and routinely would be to establish a program or forum similar to that of Oil and Gas UK's PILOT program. PILOT is an O&G taskforce which is a unique partnership between the U.K. O&G industry. It involves operators, contractors, suppliers, trade unions, SME's and government working in cooperation. In order to have an effective and functional relationship between industry and BSEE, a program or forum such as PILOT could foster trust, open communications, functional perspective and direct feedback for both industry and BSEE. A third party organization like the

Center for Offshore Safety or the Ocean Energy Safety Institute could serve as a data repository and information clearinghouse.

In order for industry to provide accurate information, there would have to be a non-retribution process in which to make reports, especially if self-reporting is possible. If industry feels they will be subject to negative impacts from data collected, they will not make accurate reports. BSEE could incorporate into regulations a process similar to that of the FAA and its third party certification, audit, and self-reporting systems. The FAA Voluntary Disclosure Reporting Program allows air carriers and regulated entities to self-report apparent violations. Under this program, a certificate holder or owner will receive a letter of correction in lieu of a civil penalty for self-reporting violations, apparent violations, or instances of non-compliance. The FAA believes that a cooperative and advisory approach to violations or issues will enhance and promote safety.

The Environmental Protection Agency's (EPA) Audit Policy includes a self-reporting program where by industry organizations can report environmental violations. This program provides incentives that encourage regulated entities to voluntarily come into compliance with federal regulations. The EPA program includes a confidentiality process where-by, when a submitter self-discloses violations, if they claim the material is CBI, the EPA must follow the CBI regulations.

Such a hybrid solution does offer a number of practical advantages including industry collaboration, monitoring efficiency and regulatory adaptability. We also note that BSEE has already taken some preliminary steps in this direction by adopting API guideline Q1.

6.3 Reporting Requirements

As part of a functional LCM system, data collection and reporting is a key element. Regardless of which LCM regulatory approach BSEE pursues, it is recommended that BSEE carefully consider what LCM data it requires and explore automated reporting standards for industry. Given clear and defined levels for reporting, an LCM system should integrate automated failure reporting for all reportable incidents.

The API standard Q1 and Q2 already provides a structure with standardized forms that industry can fill out in order to participate. If applied across the industry, API standards can help standardize the reporting of data, thus increasing the functionality and ease of analysis once collected.

The incorporation of industry standards like IADC or API standards would likely face less resistance from industry than a prescriptive approach, particularly industry-accepted and practiced standards. By having clear, understandable, and uniform definitions and reporting requirements, this should result in safety or risk metrics that BSEE can use as indicators to show the trends over time in safety. While a zero incident goal might not be achieved immediately, capturing comparable data and using that data to improve safety and increase compliance should provide percentage improvements over time.

7. Conclusion

A mandatory LCM system for the O&G industry may prove beneficial to BSEE in preventing future accidents related to equipment failures. Several companies already have established LCM systems as part of their business models and there are numerous software applications available to support an effective LCM system. An effective LCM system ensures industry is monitoring system performance, planning, recording and optimizing equipment maintenance, managing spare parts, documenting and correcting failures as they occur, and ultimately, improving system reliability and performance. An LCM system enhances the O&G industry members' visibility and awareness of the system performance and provides key insights into the health and status of equipment that is critical for safe system operations.

BSEE is faced with a decision as to the type of LCM system it chooses to implement. While a prescriptive approach may reduce liability for specific systems and components, BSEE would need to identify what the components are to be included in the LCM system, and whether they are being properly maintained. As such, an LCM system would contain a significant amount of information not typically collected by the agency and may generate proprietary data concerns with agency databases. BSEE needs to determine if these data would need to be submitted to the agency or simply maintained by industry and be subject to inspection by BSEE. Such a prescriptive system would not address any systems or equipment not previously identified. In addition, BSEE may have difficulty maintaining the currency of a prescriptive list of critical components due to advances in technology and changes in designs. Finally, a prescriptive approach that does not align with the current industry LCM systems is likely to meet with stiff resistance from industry, especially if compliance with it significantly increases the regulatory burden. Therefore, a BSEE-mandated, prescriptive LCM system for the offshore industry will require a significant policy effort on BSEE's part to both build consensus and ensure compliance.

BSEE is likely to have greater success in establishing LCM system requirements by adapting current industry best practices into an industry-based, performance standard. By focusing on the objectives and performance of the LCM system, rather than the specific methods, equipment, and data reporting mechanisms, BSEE's role would transition to one of monitoring and auditing the LCM system. This would provide each operator the leeway to define their own critical systems and to implement the LCM system they deem appropriate. This would typically involve the application of risk-based decision-making tools like FMECA, bowtie analysis, risk identification, or other approaches to identify critical systems and equipment that should be addressed in the LCM system. Similar to the existing Safety and Environmental Management System approach, BSEE would review industry documentation and records indicating the existence and effectiveness of the LCM system while not actually collecting the data. This approach addresses the industry concerns about sharing data and greatly enhances the likelihood of successful implementation.

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Appendix A – Task 2 and 3 Agency Template

Introduction

PROGRAM HISTORY

How long has the program(s) been in place?

PROGRAM INFORMATION, POLICIES AND PROCEDURES

Task 2, 2.3.4.2 - What type of policies, programs or guidelines are in place in regards to a LCM program from industry, trade groups or trade associations?

Task 3, 2.3.5.1 - Are failures reporting systems utilized by regulatory bodies? If so, which regulators use them? What types of systems? How long have they been utilized?

Task 3, 2.3.5.7 - Identify any commercial, for profit failure reporting systems that are available on the open market and to which industries they are associated with. Evaluate such systems and report on their cost to participate and their historical performance.

PROGRAM ELEMENTS, BEST PRACTICES AND LESSONS LEARNED

Task 2, 2.3.4.3 - What components do the various LCM programs evaluated under this contract contain? Not contain

Task 2, 2.3.4.5 - Do any of the groups evaluated under this contract make use of industry standards, recommended practices, specifications, etc. which address the contents of a LCM program? If appropriate, identify the document being used.

Task 3, 2.3.5.4 - Has the data generated from a failure reporting system ever been used by an equipment manufacturer to redesign or change equipment specifications? Provide a detailed accounting of how this process has worked for any identified occurrence.

THE ROLE OF INDUSTRY

Task 3, 2.3.5.2 - Are failures reporting systems utilized by individual companies, industry trade groups or associations? If so, which companies or industry trade groups or associations use them? How long have they been utilized?

STATUTORY OR REGULATORY ELEMENTS

Task 2, 2.3.4.1 - What type of regulations, policies, or guidelines is in place in regards to a LCM program by the regulatory community?

PROGRAM EFFECTIVENESS

How do regulators assess the effectiveness of their program(s)?

Task 2, 2.3.4.4 - How effective are the various LCM programs? How is effectiveness/performance of these programs measured? How long have these programs been in existence?

Task 3, 2.3.5.3 - How effective are the failure reporting systems in use? How is effectiveness/performance of these programs measured?

Task 3, 2.3.5.5 - How are failure reporting systems structured in regards to use of proprietary data/trade secrets in regards to equipment covered under a system, company anonymity when participating in such a system (is anonymous reporting effective and how is it achieved? If anonymous reporting is not used can such a system still be effective?) and how is data from the system distributed and utilized by a company or a regulator to mitigate risk.

Task 3, 2.3.5.6 - Are safety/environmental incidents included in a failure reporting system or just equipment malfunctions/upsets? If not, are they reported separately? If they are part of the failure reporting system include in assessment of them.

Task 3, 2.3.5.8 - Define the associated data analysis requirements required in a failure reporting system and specify what data needs to be collected for regulatory purposes.

PROGRAM OUTCOMES

How do regulators evaluate outcomes and satisfaction with their program(s)?

Task 3, 2.3.5.9 - Develop chart flow diagrams of failure reports from origin back to OEM, service providers, and the regulatory body for any systems evaluated.

EFFECTIVENESS DATA

Task 3, 2.3.5.10 - Identify examples of OEM and service provider utilization of such failure reports in product assessment and improvement and report on how well it has worked.

Provide available data on the program's effectiveness based on the prevalence or avoidance of various consequences.

LIABILITIES

Determine the effect, if any, of each program example on the legal liabilities of the government regulatory and the members of the regulated industry.

POTENTIAL APPLICATION TO BSEE

Describe how this program may be applicable for BSEE use?

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