Interim Report

Effectiveness of Safety and Environmental Management Systems for Outer Continental Shelf Oil and Gas Operations

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381 Elden Street
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Subject: Interim Report on the Effectiveness of Safety and Environmental Management Systems for Outer Continental Shelf Oil and Gas Operations

Dear Mr. Slitor:

In response to a request of the Minerals Management Service (MMS)—now the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE)—the Marine Board, under the auspices of the Transportation Research Board of the National Academies, formed a committee that is examining methods for assessing the effectiveness of an operator's Safety and Environmental Management Systems (SEMS) program on any given offshore drilling or production facility. The committee membership includes National Academy of Engineering (NAE) members and practitioners and academicians who bring a broad spectrum of expertise that includes the areas of safety management, human factors, risk assessment, organizational management and management systems, offshore engineering, offshore platform design and construction, offshore operations, and policy as well as the areas of safety regulations and inspections in related industries (see Appendices A and B).

This letter constitutes the interim letter report required in the committee's revised statement of task, dated January 31, 2011 (see Appendix C). This letter report presents nine methods for evaluating the effectiveness of an operator's (i.e., lessee's) SEMS program, presents the benefits and disadvantages of each method, identifies entities that could perform the audits, specifies the range of potential roles and qualifications of the auditors and of the BOEMRE inspectors who will conduct or oversee the SEMS audits, or both, and presents various methods that could be employed to conduct the audits.

BACKGROUND

BOEMRE has broad regulatory authority over energy operations on the U.S. Outer Continental Shelf (OCS), including oversight responsibility with respect to the offshore platforms involved in drilling and production of oil and natural gas. Included in BOEMRE's oversight authority is the responsibility to conduct safety audits of each platform at least annually as well as periodic unannounced "spot" audits, the intent of which is to make offshore facilities safer. The hope is that the audit process will encourage owners and operators to develop a healthy and viable safety culture on offshore facilities and that, if there are potential problems, they will be identified during the audit process and subsequently addressed, thereby reducing the likelihood of a major incident.

In 1990, the Marine Board reviewed the MMS inspection program and made several recommendations for improvement. At that time, the inspection program mostly focused on facilities and whether they met certain standards. At each visit, inspectors worked through a potential incidents of noncompliance (PINC) checklist. Among other things, the 1990 Marine Board committee found the following:

1. The emphasis on compliance with hardware-oriented PINCs fostered an attitude of "compliance equals safety" that can actually "diminish the operator's recognition of his primary responsibility for safety."[1]

2. The "majority of accident events occurring on the OCS in a representative year (1982) were related to operational and maintenance procedures or human error that are not addressed directly by the hardware-oriented PINC list."[2]

3. "Third-party inspection by private sector contractors (alternative 4) would not diminish and would probably increase the tendency of operators to abdicate safety responsibility to the inspecting organization."[3]

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[1] National Research Council, *Alternatives for Inspecting Outer Continental Shelf Operations*, National Academy Press, Washington, D.C., 1990, p. 80.

[2] National Research Council, *Alternatives for Inspecting Outer Continental Shelf Operations*, p. 81.

[3] National Research Council, *Alternatives for Inspecting Outer Continental Shelf Operations*, p. 81.

4. “Self inspection (alternative 5), while it would pinpoint the operator’s responsibility, would be unsuitable because the MMS oversight function would be too tenuous.”[4]

The report recommended that inspections instead focus on a sample of PINCs and devote greater resources to unannounced inspections as well as increased analysis of incidents and accidents and data collected by inspectors. MMS should “place its primary emphasis on detection of potential accident-producing situations—particularly those involving human factors, operational procedures, and modifications of equipment and facilities . . . .”[5]

For the latter to become more useful, the committee recommended that the quality and quantity of inspection data be considerably enhanced to allow MMS to take more of a risk assessment approach to inspections. Ultimately, the committee hoped that MMS would collect sufficient information about each platform to allow for development of risk indices that MMS could use to allocate more of its resources to platforms at higher risk. In the main, however, the committee stressed that the private operator was the primary responsible agent for ensuring safe operations and that MMS should structure its program to reinforce that awareness among operators.

MMS adopted some of the recommendations made in the 1990 report and spurred the industry to develop American Petroleum Institute (API) Recommended Practice (RP) 75, *Development of a Safety and Environmental Management Program for Offshore Operations and Facilities*. Industry was encouraged to voluntarily adopt safety and environmental management programs (SEMPs). In mid-2009, MMS proposed a rule that would have required offshore operators to adopt four of the 12 elements of API RP 75.

In April 2009, MMS again approached the Marine Board to request that the current study be conducted to review the MMS inspection program for offshore facilities to assess its effectiveness in protecting human safety and the environment. The Committee on Offshore Oil and Gas Facilities Inspection Program of the MMS was tasked with

[4] National Research Council, *Alternatives for Inspecting Outer Continental Shelf Operations*, p. 82.

[5] National Research Council, *Alternatives for Inspecting Outer Continental Shelf Operations*, p. 83.

- Examining changes in the inspection program and process since the 1990 study by the Marine Board;
- Reviewing available trend data on inspections, safety, and environmental damage;
- Examining analogous safety inspection programs in other regulatory agencies and other nations for lessons that could be applied to MMS inspections;
- Considering changes in industry's safety management practices since the 1990 Marine Board report and the implications of these changes for MMS inspection practices;
- Considering the effects of the current inspection program on offshore safety and environmental protection; and
- Recommending changes, as appropriate, to the inspection program to enhance effectiveness.

The committee was appointed in November 2009 and held its first meeting the following month. In March 2010, a subgroup of the committee made site visits to the MMS Pacific OCS Region and to the California State Lands Commission. The committee also scheduled a site visit in May of that same year to the MMS Gulf of Mexico Region. This visit, however, was overtaken by the unfolding events of the *Deepwater Horizon* explosion, blowout, and oil spill.

In the aftermath of the *Deepwater Horizon* event, the Department of the Interior conducted a reorganization of MMS, which was renamed BOEMRE. During this process, BOEMRE officials asked that this project be put on hold while the agency reevaluated its approach to safety.[6]

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[6] The agency is still undergoing major structural changes. The reorganization will transform BOEMRE into three separate bureaus: the Bureau of Ocean Energy Management (BOEM), the Bureau of Safety and Environmental Enforcement (BSEE), and the **Office of Natural Resources Revenue (ONRR)**. The royalty and revenue management functions of MMS including, but not limited to, royalty and revenue collection, distribution, auditing and compliance, investigation and enforcement, and asset management for both onshore and offshore activities [has been]…transferred to **ONRR.** "BOEM will exercise the conventional (e.g., oil and gas) and renewable energy-related management functions of MMS not otherwise transferred pursuant to **Secretary Salazar's Order 3299** including, but not limited to, activities involving resource evaluation, planning, and leasing. BSEE will oversee the safety and environmental enforcement functions of MMS including, but not limited to, the authority to inspect, investigate, summon witnesses and produce evidence, levy

Then, in October 2010, BOEMRE issued a final rule requiring adoption of API RP 75 with minor revisions as defined in the rule and retitled *Safety and Environmental Management Systems (SEMS)*. SEMS lays out multiple requirements for safe and environmental operations, including requiring specific written plans for operating practices, hazards analysis, management of change (MOC), safe work practices, training, mechanical integrity, emergency response, and incident reporting. RP 75 recommends that practices be audited by a qualified party, which could include individuals employed by the same company, on a regular schedule. In contrast, the final SEMS rule requires that these audits be conducted by an independent third party (I3P).

In the proposed rule, BOEMRE recognized that its inspection program was too focused on mechanical integrity and that mechanical failures represent a small minority of incidents. With issuance of the final rule, BOEMRE's approach to safety and environmental protection shifted from reliance solely on inspections of hardware-oriented PINC items to also requiring operators to specify how they will manage safety holistically to avoid injury and spills. There is a proposed rule to assure effective implementation of these programs through third-party audits. Accordingly, BOEMRE's request for a revised scope of this study reflects its interest in seeking guidance on how SEMS programs should be evaluated and their effectiveness assured.

STUDY OBJECTIVE AND CHARGE

After MMS was restructured, BOEMRE requested that the scope of this study be changed from a review of the agency's offshore platform safety and environmental inspection program to provision of guidance on how the agency should evaluate and ensure the effectiveness of the new SEMS practices that will be required of offshore operators effective November 15, 2011. Thus, this project was refocused and restarted in late January 2011.

Under the new agreement with BOEMRE, the committee (renamed the Committee on the Effectiveness of Safety and Environmental Management Systems for Outer Continental Shelf Oil and Gas Operations) was tasked with preparing this interim report to identify

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penalties, cancel or suspend activities, and oversee safety, response, and removal preparedness" (http://www.boemre.gov/ooc/newweb/frequentlyaskedquestions/frequentlyaskedquestions.htm).

potential methods for assessing the effectiveness of a company's SEMS program and to describe the pros and cons of each method as they are known to this point. This interim report was developed through open- and closed-session meetings, discussions, and subsequent correspondence. The report then went through independent peer review following standard National Research Council (NRC) procedures. (See Appendix D for a brief description of the review process and the list of reviewers.) The final report, to be completed later this year, will present the committee's assessment of different methods for auditing an offshore drilling and production SEMS program and will recommend what it considers to be the best method. The report will not be released until after the release of the report of the NAE–NRC Committee for the Analysis of Causes of the *Deepwater Horizon* Explosion, Fire, and Oil Spill to Identify Measures to Prevent Similar Accidents in the Future, so that the findings and recommendations of that committee's work on drilling operations can be taken into account.

GOAL OF SEMS

As previously noted, the BOEMRE requirement that lessees and operators of oil drilling and production operations on the OCS have a SEMS program is based on the previously voluntary guidelines established by API. The goal of these new requirements is to reduce human and organizational errors that cause work-related accidents and offshore oil spills by improving the overall safety of operations with better procedures and training.

A successful program should address both occupational and process safety. Minimizing the risks of slips, trips, and falls (e.g., lost-time accidents) is important, but it is BOEMRE's opinion that a SEMS program should also help reduce the likelihood and consequences of major organizational and system failures that could result in other accidents similar to the *Deepwater Horizon* event.[7] A platform that has managed to maintain multiple years of operations free of occupational injuries may still be susceptible to the development of high-consequence events.[8]

[7] Briefing by Douglas Slitor, Acting Chief, Office of Offshore Regulatory Programs, BOEMRE at the committee meeting on March 3, 2011.

[8] J. Reason, Achieving a Safe Culture: Theory and Practice. *Work & Stress*, Vol. 12, No. 3., 1998, pp. 293–306.

According to BOEMRE,[9] to be effective, operators' implementation of SEMS needs to be evaluated and tracked through an auditing mechanism. The auditing approach adopted by BOEMRE will have a direct effect on the short- and long-term success of the SEMS program. Auditing programs vary across multiple dimensions, such as the quantification of goals, the frequency and type of audits, the size and severity of any reward or penalty assessment, and the collection of data to determine program effectiveness. The audit approach should help foster SEMS programs that are adopted throughout all levels of management. An operator that is merely trying to avoid penalties by going through the motions will not be effective in controlling on-platform risks. SEMS should be much more than a paperwork drill, and the auditing process should encourage this broader perspective.

SEMS and a Culture of Safety

The management of safety within an organization is ultimately a reflection of its safety culture. It is hoped that effective implementation of SEMS will have a positive impact on the safety culture of companies operating on the U.S. OCS; however, this will not be known until trend data are available and analyzed.

Although a safe culture is a goal of organizations and attempts are made to measure it, people often find it difficult to describe a safe culture in concrete terms. According to James Reason, "Uttal's (1983) definition of safety culture captures most of its essentials: 'Shared values (what is important) and beliefs (how things work) that interact with an organization's structures and control systems to produce behavioural norms (the way we do things around here).'"[10] Safety management should be integrated into a company's organizational systems and management practices to achieve a positive culture of safety. Safety management systems are more than a set of policies and procedures; they also include how policies and procedures are implemented through work practices and the commitment of resources and support in the workplace that can truly make an impact on safety culture.

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[9] Briefing by Douglas Slitor, Acting Chief, Office of Offshore Regulatory Programs, BOEMRE at the committee meeting on March 3, 2011.

[10] J. Reason, Achieving a Safe Culture: Theory and Practice, p. 294. See also B. Uttal, The Corporate Culture Vultures, *Fortune Magazine*, October 17, 1983.

For a culture of safety to exist and grow, there should be reciprocity between corporate and (individual) employee values, beliefs, and perceptions. SEMS can create the backbone of the safety culture upon which organizations build these internal reciprocal relationships that lead to a better culture of safety. In other words, a culture of safety requires commitment, engagement, and execution from all levels of the organization. It is this ownership and engagement that reshapes safety culture into a continuing, long-term commitment to improve.

A common problem for some companies is the tension between organizational mandates regarding safety and messages for efficiency in terms of time and money. Companies are continually making decisions that trade off safety against other objectives (e.g., time and cost). Without a framework that keeps safety concerns elevated to an appropriate level, suboptimal decisions can be made. This can happen when the conflict of responsibility and accountability with respect to many different organizational goals (e.g., safety, time, and production) ensures that the target with the most forceful message from top management will prevail. Building trust that top management will support decisions to override other priorities with safety is the only way to achieve a culture of safety; however, SEMS alone cannot achieve this.

With its audit program, the Bureau of Safety and Environmental Enforcement (BSEE) will be in a unique position to influence how SEMS is implemented and integrated in an organization. To achieve reliably safe operations, more than a well-defined SEMS is needed—people in the organization must actually use SEMS and improve it on a continuing basis. Thus, auditing has to extend beyond the existence of a SEMS—and the existence of documentation that supports its use—to assuring that what is described in the SEMS is actually the way people work. An effective audit program would extend assurance beyond paper verifying records to how the SEMS is used to guide what individuals in the organization do to ensure safe and environmentally responsible operations. Perhaps one useful way to explain the interaction of process and culture is the organization–individual–able-to–want-to matrix (Figure 1).

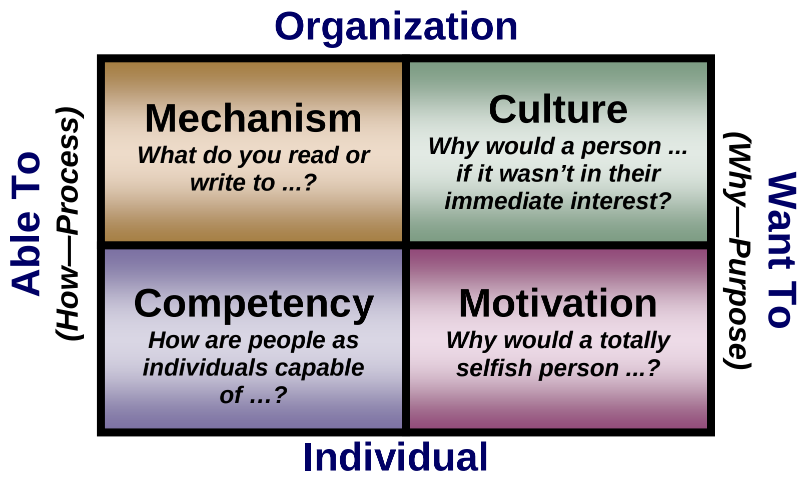

Figure 1. Interaction of process and culture.
Source: J. Ford Brett, committee member, and adapted by the committee.

This matrix illustrates the requirements for an action to reliably occur in a real organization. For something to reliably occur, the *organization* as a whole, and each *individual* in the organization, needs to be *able to* and needs to *want to* accomplish the action. As a brief overview, the *organization–able-to* quadrant of the matrix describes the mechanism an organization would use to operate safely and is basically the SEMS plan and supporting documentation. For example, without an effective SEMS plan and appropriate documentation, an organization could not operate safely; however, great plans, and even great documentation, do not mean the organization will be safe. The *individual–able-to* quadrant of the matrix is competency and describes how people as individuals are capable of executing the requirements of safe operations. There may be great plans, but without competent individuals, they cannot be carried out. The *individual–want-to* quadrant is motivation and describes those factors in the actual organization that would cause a totally selfish person to want to work safely. For example, if people really are totally unmotivated to report incidents (e.g., because bonuses are lost or because the paperwork is just too much of a hassle) then more training on how to spot incidents will not address the issue. Finally, the *organization–want-to* quadrant is the culture or behavioral norms that cause people to act properly, even when no one is looking and when it is not in their immediate best interest.

Culture causes people to accurately report events, even when they are at fault, because the norm is telling the truth.

Very briefly, if one of these elements is missing, there will be a bottleneck in the organization's ability to work safely and with environmental responsibility, and more emphasis of the other elements will not address the problem. If *motivation* or *culture* is missing, training or the detailed process will not be the root cause of an incident. This type of analysis can be helpful in creating ways to assure that SEMS is more than a paper exercise.

Guiding Questions for Evaluation or Audit

Any audit process has multiple opportunities for checking the strength and effectiveness of each platform's instantiation of SEMS. A sequence of guiding questions provides a preliminary structure for the audit (as shown in Figure 2):

1. **Is a SEMS plan in place?** Is the plan complete? Is there a document to read? Has the owner or operator structured a plan that covers all the necessary personnel, equipment, and situations?
2. **Is the plan feasible and effective?** Given that a plan is in place, how good is the plan in reducing risks? If the steps outlined in the plan are followed, will they be successful in meeting program safety goals? Are sufficient resources available to comply with the plan? How does the plan compare with plans that have been developed for other similar platforms and have been shown to be effective?
3. **Do personnel know about the plan?** A well-written and carefully thought-out program will not succeed if the personnel required to follow it are not aware of it. Is there a way to track components of SEMS with the necessary personnel? As personnel are replaced, is there a process by which new personnel are introduced to their responsibilities? Is the plan pervasive throughout the organization?
4. **Can and do personnel effectively carry out the plan?** That personnel are aware of the program does not mean that they can follow it effectively. Is a training program in place? Are there periodic tests and drills with which personnel can demonstrate their familiarity and expertise with details of the plan?

5. **Is the plan affecting safety?** The goals of SEMS programs are to improve both occupational and process safety. Are metrics that permit verification of the SEMS plan being recorded and tracked? Is the plan being used to instill and encourage a healthy safety culture? Long-term effectiveness can only be assessed through the comparison of tracked measures with baseline data. Are occupational and process safety near-miss events being recorded and evaluated? A careful definition of performance metrics would allow for comparisons across platforms, rigs, operations, lessees–operators, and regions. It would also facilitate international comparisons.

Each question requires a different audit approach; a different data collection requirement; a different audit schedule; and, potentially, a different type of trained auditor. Strengths and weaknesses of alternatives for these options are discussed in the following sections.

METHODS FOR ASSESSING EFFECTIVENESS

To date, the committee has identified nine methods for assessing the effectiveness of an operator's SEMS program: audits, compliance inspections, peer reviews–assists, key performance indicators, whistleblower programs, periodic lessee reports, tabletop exercises or drills, SEMS monitoring sensors, and calculating the risk with SEMS in place. Some of these methods can be further subdivided. These nine methods, however, are not mutually exclusive and elements of each could be combined to develop the most effective evaluation program. A general description of each method is provided below. Table 1 summarizes each method, in no particular preferred order, including the pros and cons of each as well as notes for clarification.

Audits

This is the classic audit consisting of a comprehensive systematic collection and review of information to ensure the SEMS program is being maintained and operated as

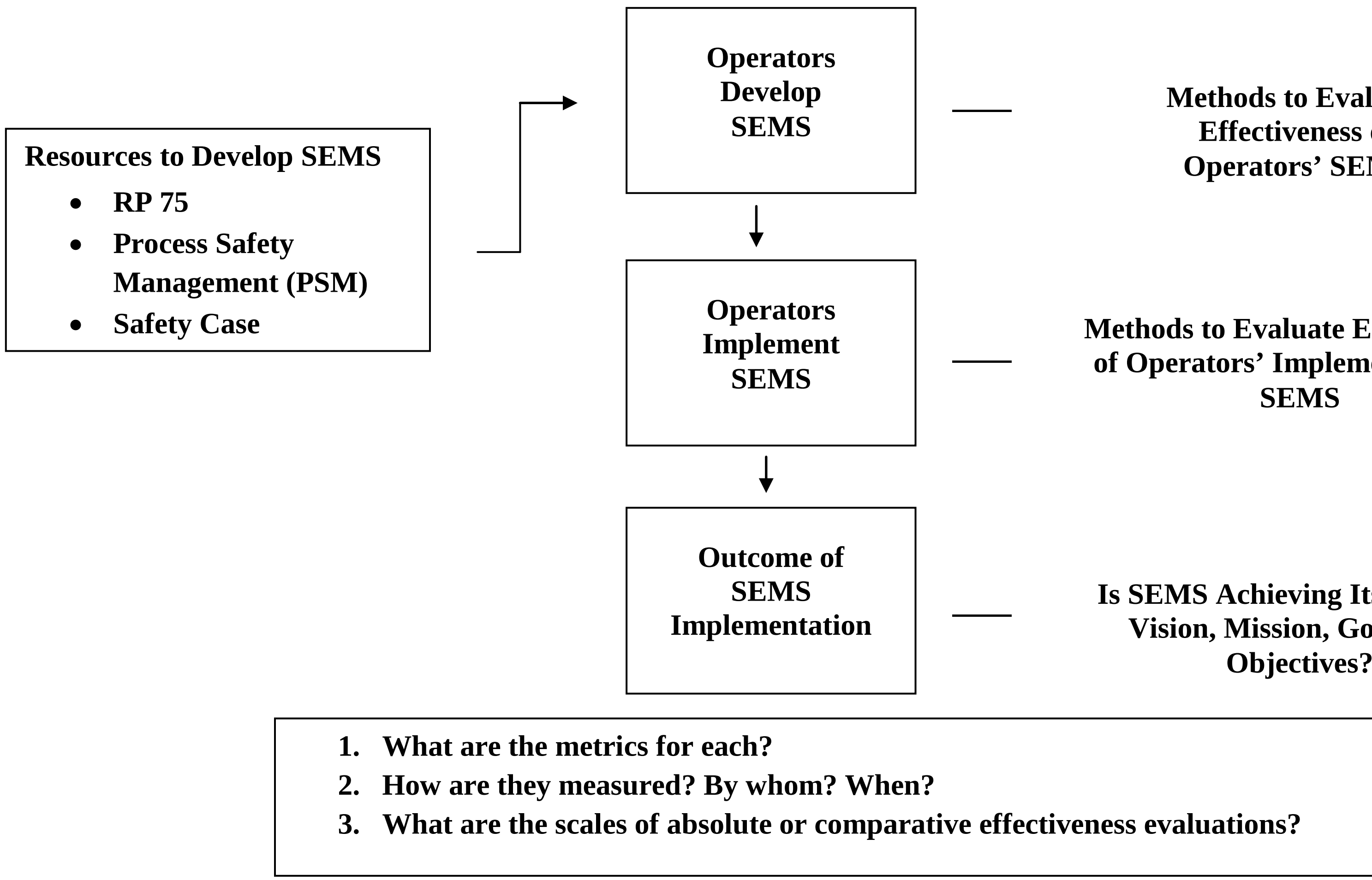

Figure 2. Scope of SEMS study.

intended. Where possible, the audit should verify objective evidence showing conformance to the SEMS program. The audit is typically performed by an independent organization. There may be (*a*) periodic, (*b*) surprise or random, or (*c*) event-driven audits.

Compliance Inspection

This is one of the simplest forms of SEMS verification. The intent is to verify with little time and minimal inspector training that at least portions of the SEMS program are operating. It is not meant to be a comprehensive audit such as that described in the previous section; rather, it provides a general indication of the state of the SEMS program by verifying specific components. Compliance inspections take place on the offshore facility and may involve the use of checklists, interviews, witnessing, and the like. For example, the inspector may use a brief checklist to verify that SEMS items such as operating procedures, training (certificates), and emergency response plans are in place and the staff are familiar with their use. The inspections can be performed by company personnel as well as government inspectors. Having an operator from one platform conduct a compliance inspection on another platform can be instructive for both operations.

Peer Review–Assist

This is also often called the peer assist method. Respected industry peers from outside the organization, including other operators, review the company's compliance performance and SEMS implementation and then suggest helpful ideas for improvement. There may or may not be formal documentation. Peer assists are a common intra- and intercompany activity for technical and economic issues and have been found to work well in the offshore as well as other industries. There are different protocols for this method (e.g., different levels of required response to peer recommendations) that may vary from an informal process with no formal recommendations and no written record, to a formal process with formal recommendations and written responses to recommendations, to some variant in between. One goal of the peer review–assist method is to have an independent set of eyes focusing on a company's operations with the sole purpose of helping that company improve. This method is based on the premise of promoting a “don’t-blame-let’s-improve” culture. The aviation industry is one example where this approach is employed.[11]

Key Performance Indicators

Key performance indicators (KPIs) are commonly used to evaluate a program’s success or the success of a particular activity, in this case SEMS. KPIs work well when there are clear objective metrics that can be quantified, such as are often used in operations (e.g., barrels of oil produced or lost-time incidents). The difficulty for SEMS is to determine the specific metrics that will measure the effectiveness of the SEMS program.

Whistleblower Programs

This method involves an internal or external person (or organization) bringing to attention that some components of the SEMS program or the complete program are not being implemented correctly or are being falsified. In order to be most effective, such a program would have to protect the identity of the informant as well as guarantee no repercussions (e.g., an employee losing his or her job). These types of programs often involve an I3P that handles the comments, perhaps as part of a comprehensive compliance system, to ensure the comments are confidential, properly vetted, and appropriately acted on. This program is used in numerous other industries, so there are plenty of examples for SEMS programs to refer to.

Periodic Lessee SEMS Report

This is a periodic self-generated report by the lessee describing the effectiveness of its SEMS program. Although produced by the lessee and perhaps open to questions about accuracy, the report does force the lessee to take an active approach to SEMS implementation and monitoring. The contents of the report can range from an open format defined by the lessee to a specific format and content required by the regulator.

[11] See, for example, http://www.nasa.gov/offices/oce/appel/ask/issues/40/40i_peer_assist.html.

Tabletop Exercises or Drills

This involves special drills and tests of an operator's SEMS program and can be performed on a planned or surprise basis. Similar drills are already performed on offshore facilities related to life, safety, and environmental releases. This includes the use of computer-based virtual reality (VR) models to realistically assess operator skills and reactions to special situations. The use of VR models minimizes the impact on field operations and, if planned correctly, can also incorporate some of the other methods described here, such as SEMS monitoring sensors. Because this type of SEMS drill is not commonplace, this approach would require considerable preplanning by both the operator and the regulator to make the drill specific to testing the effectiveness of a SEMS program.

SEMS Monitoring Sensors

This approach uses mechanical sensors that monitor items such as pressures, temperatures, and flow rates to develop metrics that can be used to determine SEMS effectiveness; however, the specific monitors, their relationship to SEMS, and how such a system would work have yet to be determined. Some of these monitors may be in place already as part of normal production operations, while other new monitoring devices may need to be developed specific to SEMS metrics. Ideally, these systems would be able to send information directly back to shore for real-time SEMS monitoring.

Calculation of Risk with SEMS in Place

This involves a formal quantitative risk assessment (QRA) for the platform based on SEMS-specific data. The change in the QRA risk level with modification or updates to the SEMS program can be used to monitor the program's effectiveness, although this is a computed theoretical effectiveness. One advantage of this method is that the owner can use the QRA risk level to determine the effectiveness of alternative SEMS-related modifications and upgrades to assist in determining the best approach (from a SEMS perspective).

Table 1. Methods for Assessing the Effectiveness of SEMS

Method	Description	Pros	Cons	Notes
Audit	Review of the implementation and quality of SEMS at both corporate and platform level Platform level may be all platforms or a sampling Scope (e.g., comprehensive or selected components) and details (time interval, auditing protocols) can be varied	• Proven method • Established auditing protocols available for process safety management (e.g., API, American Institute of Chemical Engineers) • Scope and details can vary	• Can only provide a reasonable assurance that the system is effective • Specific protocols need to be developed for defined scope • Auditor required to be expert at SEMS • Several auditors may be required in order to look at all SEMS areas	
Periodic audit	Planned in advance on a regular basis, typically 2- to 3-year intervals	• Can be scheduled to meet BSEE requirements • Can be a comprehensive audit	• Cost and time • Need to develop specific protocols for SEMS audit	Guidelines for meeting BSEE audit requirements
Surprise or random audit	Unannounced; a combination of randomly selected SEMS across all owners	• Instantaneous assessment of state of SEMS implementation	• May disrupt normal activities (e.g., drilling or testing) • May not be comprehensive	"Surprise" means several days' notice, not instantaneous
Event-driven audit	Triggered by events such as injury or death, pollution, a near miss, and noncompliance	• Immediately corrects SEMS issues, if applicable	• Reactive, lagging assessment • May not reflect processes in place prior to incident	May be required in any case by regulations

Method	Description	Pros	Cons	Notes
Compliance inspection	Onboard SEMS check by the day-to-day BSEE inspectors; regional inspectors can also perform SEMS check		• Scope of SEMS check limited because of responsibilities for inspections of all other mandatory requirements	
Checklist	Checklist to ensure SEMS is in place on platform Checklist scope and details may vary	• Simple to implement with minimal training • May quickly identify deficiencies with SEMS program and implementation	• May only assess compliance with paperwork or system; limited assessment of SEMS program's effectiveness • Platform specific; not a corporate-wide check • Content and quality can vary extensively • Must develop checklists	
Interviews, witnessing, etc.	Interviews or other communication with platform personnel to determine whether they understand the SEMS program, including possible test drills May be concurrent with administering checklists	• Can provide information to assess whether personnel on platform are knowledgeable and use SEMS	• Can be subjective • Reliant on interviewer skills • Additional SEMS training required, perhaps substantial • Time consuming	California State Lands Commission program is an example
Peer review–assist	Assessment of SEMS implementation by a team composed of peers from the industry	• Qualified and experienced in SEMS • Nonthreatening identification of catastrophic weaknesses and opportunities to improve • Good potential to learn from each others' SEMS	• Independence may be questioned • Potential conflicts of interest and confidentiality • Potential legal liability issues related to discoverability of recommendations and recommendations given in good faith that have poor outcomes	

Method	Description	Pros	Cons	Notes
Key performance indicators	Use metrics from corporate- or platform-specific data to assess SEMS effectiveness Metrics can be currently reported ones [e.g., incidents of noncompliance (INCs), spills, accidents, near misses] or expressly developed new ones [e.g., number of changes (MOC), SEMS INCs]	• Quantitative • Easy to implement • Can be automated and reported to BSEE regularly (quarterly) • Could be used to identify specific problem platforms • BSEE databases available for analysis	• Unclear as to how current metrics relate to SEMS effectiveness • New metrics may need to be developed • If metrics do not accurately reflect safe conditions, they could create complacency	BSEE can establish specific SEMS INCs
Whistleblower program	Policy and programs by owner for anonymous reporting of events or situations by employees or other persons to complement normal reporting and communication channels that would lead to better SEMS implementation	• Proactive for identifying corrective actions • Evidence of management's commitment to SEMS • Engages staff day to day • Easy to implement	• Lagging indicator of problems already in place • Disgruntled persons can report false information • Dependent on culture • Requires fast and transparent follow-up program by owner	May be available in other industries (e.g., nuclear, aviation)

Method	Description	Pros	Cons	Notes
Periodic lessee SEMS report	Quarterly, biannual, or yearly specific report from the lessee on the status and effectiveness of its SEMS program Scope and details of these voluntary reports can vary	• Keeps SEMS relevant and recent in terms of operator's processes • As voluntary submissions, these may be useful when performing mandatory SEMS audits	• Accuracy of self-report can be questioned • Can be onerous on operator • Scope and detail are not defined and may need to be developed	Report context and content are current and relevant; may be corporate level rather than platform specific
Tabletop exercise or drill	Planned or surprise drill with specific actions to test SEMS; similar to spill drills Can vary from simple to complex exercises depending on the scope of SEMS tested	• Can become a subset of existing drills • True reflection of SEMS in action	• Cannot test all SEMS—would have to be a selection • Would require much preplanning by owner and BSEE • Can only be applied to a limited number of facilities • Time consuming • May require dedicated BSEE personnel and skill set	
SEMS monitoring sensors	Tracking onboard sensors to establish specific metrics for SEMS purposes	• Quantitative SEMS measure • Possible future development of SEMS-specific sensors • Can send data back to shore for evaluation	• Need to identify how these sensors may reflect SEMS issues	

Method	Description	Pros	Cons	Notes
Calculation of risk with SEMS in place (QRA)	Specific quantitative methods that use owner's SEMS program as well as statistics from platform operations to determine effectiveness of SEMS over time	• Measurable • Can see changes in performance over time	• Quantitative, results can vary between QRA approaches • Need data over time to see trends • Need baseline data for statistical analysis • Output depends on model assumptions and details	

WHO PERFORMS THE AUDIT

In the previous section, various methods for measuring the effectiveness of SEMS were identified. No matter which method is selected, BSEE will have to verify that operators have a comprehensive SEMS program in place and that it is operating effectively. That is, BSEE will need to have some mechanism in place to be able to conduct, participate in, or review SEMS audits that are conducted. In this section, various alternatives to accomplish this goal are discussed.

Operator Reports Audit Results

SEMS requires operators (i.e., lessees) to audit their SEMS program within 2 years of the effective date of the SEMS final rule, which is November 15, 2011, and then every 3 years thereafter. The audit is to consist of the company's overall SEMS program and 15% of the platforms operated by the lessee. The current requirement is that the audits can be performed by qualified in-house staff or by I3P contractors.

Under the operator-reports-results method, operators would be required to submit periodic [quarterly, annual, or event-based (incident-based)] reports of the status of their SEMS program and the results of the audits. BSEE would review these submittals at the regional level. On the basis of incidents, the reports received, suspicions that the audits are incomplete, or input from the compliance inspectors, BSEE might then elect to conduct its own audit as already allowed under SEMS. This process is similar to the one now in effect under the Occupational Safety and Health Administration (OSHA).

Benefits: This method puts the burden for SEMS implementation and actual performance totally on the operator. One of the purposes of SEMS is to make a positive impact on the culture of safety of operators. SEMS elements have been identified as critical to, but not sufficient for, creating a culture of safety. For a culture of safety to exist, there must be a mind set of focusing on safety throughout the organization. The more the operator owns the process, the less the tendency for the operator to equate safety with compliance with prescriptive regulations.

Disadvantages: This method relies on operators to perform in good faith. There is a public perception that the industry has a tendency to sacrifice safety for profit and must be forced by threat of penalties to operate in a safe manner. In addition, BSEE would have to issue and police the qualifications required for both in-house auditors and I3Ps.

Independent Third Party Performs Audit

Benefits: This introduces a required third party to work with the industry, and it should provide better assurance that qualified individuals perform the audit.

Disadvantages: On the one hand, the operator would pick and pay for the I3P. Therefore, an operator who had not fully bought into the idea that SEMS would positively affect safety might pick the most lenient and least expensive I3P. An operator interested in doing the minimum required for compliance might not be so conscientious in its choice of an I3P. The operator might believe that the auditor has some level of responsibility for safety and making sure that the SEMS program is operating correctly, splitting the responsibility for creating a safety culture between the operator and auditor in the operator's mind. In this case, there might be little or no improvement in safety culture over the current method.

On the other hand, those committed to SEMS would be forced to hire an I3P rather than perform the audit themselves. This might reduce the operator's ownership of the process, with perhaps a slightly negative effect on safety culture. Additionally, the issue of who audits the auditor would come into play.

Operator and BSEE Perform Required Audits Jointly as a Team

In this method, the required audits would be performed by a combined team of BSEE and operator personnel. BSEE would still retain the right to do an audit by itself on the basis of incidents or observations of compliance inspectors.

Benefits: Being a member of the audit team would make BSEE part of the team creating the safety culture and would enable BSEE to develop a much better idea of the safety culture of the operator and the platforms audited.

Disadvantages: This method would require more BSEE staff than are needed when the operator reports the results of the audit.

BSEE Performs Required Audits

Under this method, BSEE would take on direct responsibility for performing the required periodic audits and any other audits based on periodic reports, incidents, or observations of compliance inspectors. This is similar to the way that the California State Lands Commission has conducted audits for the past 15 years of SEMP compliance on platforms in California state waters. The California State Lands Commission has required operators to comply with API RP 75 (SEMP) since the 1990s.

Benefits: From the standpoint of public perception, this is perhaps the best alternative, as it would put BSEE directly in the role of assessing the effectiveness of the SEMS program.

Disadvantages: Of the methods discussed, this one would make the most intensive use of BSEE staff. This method also would do the least to create a culture of safety, as passing the BSEE audit might become simply a paperwork compliance issue (i.e., What do I need to do to pass the audit?).

Industry Safety Committee Performs Required Safety Audits

This method would be similar to that employed in the nuclear industry. Operators would contribute personnel to an independent agency for a specified period of time. These people would perform the required safety audits. After their terms were completed, they would return to their original companies.

Benefits: This method might result in the most informed audit teams, as companies would be encouraged to provide individuals with hands-on experience in practical aspects of operations and associated problems. It also would result in a spreading of best practices, as individuals would return to their companies, and could perhaps result in creating an industry-wide culture of safety.

Disadvantages: In contrast to the nuclear industry, which has about 12 operating companies and 100 installations to audit, the offshore U.S. industry has more than 150 operating companies and more than 3,000 installations to audit. It might be difficult to find operating companies who would dedicate for periods of 2 to 3 years the number of staff required for such an undertaking.

This method would also have the same drawbacks to creating a culture of safety that were discussed above, in that it would take the responsibility of auditing out of the hands of the operators. In addition, when auditing rigs, competitors' personnel would be exposed to company confidential materials that could prove useful in the competition for leases.

Independent Third Party Performs Required Safety Audits

The SEMS final rule includes a requirement for operators to use I3Ps to audit their systems; however, the rule does not define what constitutes an I3P. This section of the report explores the skills and qualifications that an I3P might need to possess.

There are at least three potential options available for determining the competence of I3Ps:

1. BOEMRE could determine the attributes required of an I3P and perform an assessment of each company that wished to perform this service. BOEMRE would need to maintain a register of these companies and establish a monitoring program to ensure they maintained competence.
2. The I3Ps could be self-regulating. To give an example, the classification societies formed the International Association of Classification Societies, which sets standards in the form of a quality system certification scheme with which all member societies must comply. In other words, the companies who wished to offer the I3P service would form an association that would be able to demonstrate to BOEMRE that its members would satisfy all the criteria required of an I3P.
3. An independent body such as the American National Accreditation Board could develop criteria that the I3Ps would need to meet, and this independent board would award accreditation as appropriate and would then be responsible for assessing the system by monitoring and auditing the accredited companies.

ROLE OF INSPECTORS IN SEMS AUDITS

The role of inspectors cannot be exactly defined until the audit process, the role of BSEE, and other issues are defined in more detail. Therefore, this section is limited to a brief description of the role of the compliance and regional inspectors.

The concept of having both prescriptive regulations and performance standards means that inspectors will be required to fulfill two distinct roles. Prescriptive regulations require inspection–audit processes similar in intent to those of the heritage MMS, namely, to ensure that lessees are following regulations. This means finding and reporting instances when regulations are broken. The envisioned audit of prescriptive standards could follow improved and more reliable processes, have more reliable tools and reporting methods, and so forth, but the basic idea would be the same: inspect operations, compare with regulations, and report on deviations. The compliance inspector’s role will be primarily focused on prescriptive regulations.

Properly auditing a safety management system is not only about finding and reporting deviations, but also about assessing the current state of how safety is assured and finding specific opportunities for improvement (i.e., identifying weaknesses in the system). An audit of performance standards should have the purpose not just of identifying uncontrolled or inadequately controlled hazards, but also of finding the strengths and weaknesses of the safety management system itself. The regional inspector’s primarily role will be focused on these performance standards as embodied in the operator’s SEMS.

A proper audit of a SEMS program should always find areas that can be improved. Indeed, an indication of a poor SEMS audit would be finding that everything is perfect. The determination of the degree to which a management system is in place and is encouraging a culture of safety is somewhat subjective. This is not the case for a compliance audit, in which an objective standard is used to determine whether there is compliance with a specific checklist item.

Compliance Inspector

In addition to focusing on the prescriptive regulations, the compliance inspector will focus on those aspects of the performance standards and the SEMS program that can be objectively audited. At this time, this inspector's role can be summarized briefly as follows:

- Observe operations (both on the rig and on shore) to compare the state of affairs with prescriptive regulations (mandatory laws and regulations) and the requirements of company SEMS plans (i.e., is there a written plan, and does it cover the elements specifically required by SEMS?);
- Follow a defined audit process to spot-check key elements of prescriptive regulations;
- Use BSEE audit tools (e.g., PINC checklist) to ensure a reliable audit process;
- Create audit reports that summarize audit process findings; and
- Create a separate report that focuses on potential opportunities for improvement over and above formal audit findings.

Regional Inspector

The role of the regional inspector will focus more on implementation of SEMS across an entire organization. At this time, this inspector's role can be summarized briefly as follows:

- Review compliance inspector audit(s) of an operator;
- Review SEMS, as defined by the operator;
- Review SEMS documentation and compare with SEMS definition;
- Interview key operational and engineering personnel, as well as line workers, on how SEMS works in reality (use both formal and informal interview tools);
- Create an audit report that summarizes audit process findings (e.g., differences between the SEMS program as defined and as implemented); and
- Create an audit report that summarizes the strengths and weaknesses of the SEMS program and identifies specific improvement possibilities in the program as defined by the operator.

AUDITOR QUALIFICATIONS

SEMS audits span a wide range of disciplines; thus, the auditors should be suitably qualified and trained in the audit function. The auditing organizations should be competent as well as independent. Consideration should be given to the various tasks associated with the audit function as well as to the qualifications of the individuals authorized to perform those tasks against two levels of competence: training and certification.

Training

Training programs allow individuals to become familiar with audit requirements. These programs may be structured around the elements of SEMS so that qualifications could be restricted to specific elements and individuals could be authorized to perform those particular functions. In this way, a team that carries out a SEMS audit could be composed of several individuals with different levels of competence and authorization.

Training could be performed either in house or externally. Training courses, whether performed internally or externally, may need to be developed, tested, approved, and certified. Such training courses could also be attended by BSEE inspectors so that they could include aspects of SEMS audits as part of their routine inspections. They would also be qualified to perform audits when incidents occur (i.e., when an audit falls outside the routine triennial periodicity).

Certification

Two levels of certification could be required:

1. A high-level certification to demonstrate that the organization that will be doing the audits is accredited and approved to perform the audits and
2. Certification of the individual auditors to demonstrate that they have received the right level of training and are therefore competent in the audit role.

PERFORMING AN AUDIT

As discussed previously, there may be a need to manage safety following management principles of planning, organizing, implementing, and evaluating. Table 2 shows how the various elements of SEMS address each of these principles.

Table 2. Management Principles and Elements of SEMS

Management Principle	SEMS Element
Planning	Employee participation Process safety information Process hazards analysis Pre–start-up safety review Emergency planning and response
Organizing	Operating procedures Safety work practices Training
Implementing	Contractor safety Mechanical integrity Management of change
Evaluating	Incident investigation Compliance audits

As mentioned earlier, there are the two types of events that SEMS attempts to minimize by creating a framework upon which the operator can build a culture of safety:

1. Personnel safety event: Relatively low-consequence events such as slips, trips, and falls; small spills with only localized and short-lived pollution and fires; and even those events that may lead to one or two fatalities and
2. High-impact event: High-consequence events that are extremely low in probability but relatively much higher in consequence in terms of loss of life, such as the *Piper Alpha* event, or that cause widespread or long-lived environmental damage, such as the *Deepwater Horizon* event.

As discussed previously, traditional measures of safety performance can be used to monitor progress toward improving personnel safety events. These measures can include fatalities, lost-time incidents, spills, incidents of noncompliance (INCs), and so forth. Indeed, tracking such statistics can lead to a reasonably high level of confidence in predicting which installations might be at higher risk for a personnel safety incident in the future and which will be at a lower risk for such incidents. No combination of these measures has been proven to be a good indicator of the future risk of a high-impact event, however. The year before the *Deepwater Horizon* incident, Transocean, the drilling contractor for the Macondo well, had received an award from MMS for being the safest drilling contractor in the Gulf of Mexico on the basis of these same measures. In addition, BP, the operator (lessee) for the Macondo well was one of the three finalists for the 2009 award as safest large operator in the Gulf of Mexico. The award was to be given out at the Offshore Technology Conference the first week in May 2010; however, the announcement of the winner was cancelled after the *Deepwater Horizon* disaster on April 20, 2010.

It might be possible to analyze data on accidents and near misses that, for the purposes of this report, can be defined as incidents of loss of containment of hydrocarbons. Unfortunately, unless there is a loss of life, lost-time incident, fire, explosion, or spill, loss-of-containment data are not normally captured. It is known from the many risk assessments that have been performed on offshore drilling and production systems that, even if the barriers that prevent loss of containment are breached, mitigation barriers are in place that often prevent loss of containment from becoming either a personnel safety or a high-impact event.[12]

Thus, it is extremely difficult, if not impossible, to measure the degree to which a culture of safety exists within a specific organization from readily obtainable objective data. It could be possible to identify process-specific near-miss indicators (analogous to occupational safety near-miss events). This may be a fruitful longer-term source of possible

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[12] One example is Shell's bowtie model, which incorporates both prevention strategies (including barriers) to reduce the likelihood of a hazard release (referred to as a "top event") and mitigation strategies (recovery measures) to minimize the consequences of such an event. See http://www.shell.com/static/environment_society/downloads/safety/process_safety_in_shell_lr.pdf as well as http://www.leger.ca/GRIS/BowTie.html for a description of the bowtie model.

improvement, but it will take time to develop relevant metrics and collect data to ensure they are effective. Because SEMS is necessary for a culture of safety, all an audit can do is measure, if somewhat subjectively, the degree to which the elements of SEMS are understood and applied at all levels of the organization. This can be done by first making sure the appropriate documentation is in place and available to all and, more importantly, interviewing operating staff in the field at all levels of operations to determine the degree of awareness of and compliance with this documentation. No one can ever be expected to have a perfect score in this type of analysis. All that can be hoped for is that the specific operation being audited has a reasonable score that weaknesses are recognized, and that, over time, there is continuous improvement. That is, an audit system cannot just rely on yes or no answers to a series of questions in a PINC list.

Several organizations have addressed this problem, including the California State Lands Commission, OSHA, the Mine Safety and Health Administration (MSHA), and the United Kingdom (UK) Health and Safety Executive (HSE). The committee has met with the California State Lands Commission but has yet to meet with the others.

California State Lands Commission

The California State Lands Commission requires operators to comply with what it calls Safety Assessment of Management Systems (SAMS). This is based on a joint industry project (JIP) performed in the 1990s by Paragon Engineering Services with help from the University of California, Berkeley, and sponsored by MMS, the California State Lands Commission, HSE, the National Energy Board of Canada, the American Bureau of Shipping (ABS), Chevron, and Texaco. The California State Lands Commission has been auditing SAMS performance for more than 15 years using a technique originally developed by the JIP and modified slightly with experience and has reviewed some installations three times over the years. It reports steady improvement from audit to audit, which it attributes to working with the operators to increase their compliance rather than punishing them with fines and shut-ins for areas that may need improvement.

Occupational Safety and Health Administration

OSHA requires operators of hazardous plants to maintain a Process Safety Management (PSM) program, which contains the same basic elements of managing safety that are listed in SEMS. It evaluates the plant's PSM system after a major incident. The committee has yet to meet with OSHA to better understand how the agency audits for effective implementation of the PSM program.

Mine Safety and Health Administration

MSHA was created in 1977. Among its responsibilities is the enforcement of safety and health rules in all mines and mineral-processing operations in the United States. Legislation provides that MSHA inspectors shall inspect each surface mine at least two times a year and each underground mine at least four times a year (seasonal or intermittent operations are inspected less frequently) to determine whether there is compliance with health and safety standards or with any citation, order, or decision issued under the Mine Act and whether an imminent danger exists.

MSHA pursues several activities that support its mission, such as

- Educating and training mine inspectors, mine officials, and miners;
- Testing, approving, and certifying certain mining products for use in mines; and
- Providing technical assistance to the states and small mine operators.

These are accomplished through specific mechanisms such as

- The National Mine Health and Safety Academy,
- The Approval and Certification Center,
- The Pittsburgh Safety and Health Technology Center, and
- The Directorate of Educational Policy and Development.

Equally important is MSHA's work with industry and states to develop health and safety programs. For example, its State Grants Program for miner training programs and training resource materials is used by the states and trainers to conduct health and safety training.

Recently, MSHA has been in the process of making rules for a "safety and health management program in the mines." In late 2010, MSHA held three information-gathering meetings, and proposed rules are expected in 2011. The proposed rules may be similar to those of OSHA's proposed Injury and Illness Prevention Programs. The aim is to develop a culture of safety in mines. In all likelihood, the current mandatory inspections by MSHA inspectors and MSHA penalty provisions will continue.

UK Health and Safety Executive

The UK HSE requires operators of offshore installations to develop and maintain a safety case that makes the argument that the individual risk rate for someone working on the installation is as low as reasonably practicable (ALARP). An adequately written safety case must address how the operator plans to manage safety, which will include, from a practical standpoint, most if not all the elements of SEMS, although they may be defined in slightly different terms. The committee has yet to confer with HSE to better understand how they audit for effective implementation of the safety case.

The committee's current understanding is that UK duty holders (operators) are required to employ verification bodies whose main responsibility is to ensure that the duty holder is performing its work and maintaining its safety-critical elements (SCEs) in accordance with its safety case and written scheme of verification. The duties typically performed by the verification company include

- Witnessing activities associated with testing and measuring of SCEs;
- Reviewing documentary evidence to substantiate the satisfactory demonstration of the continuing achievement of performance standards for SCEs;
- Periodically reviewing the verification process to ensure compliance with the duty holder's written scheme;
- Monitoring trends of availability and reliability of SCEs;

- Witnessing, reviewing, and document auditing of activities associated with vendor-supplied equipment where applicable to SCEs;
- Monitoring and reviewing the duty holder's modification activities where interfaces with existing or potential SCEs exist;
- Completing all documentation and reports as required in the duty holder's written scheme of verification and well examination scheme;
- Periodically reviewing the duty holder's procedures for complying with lifting legislation;
- Performing audits to verify compliance with procedures and legislation;
- Participating in failure investigations;
- Developing procedures for lifting operations and lifting equipment inspection;
- Reviewing crane maintenance inspection and testing records and issuing annual crane approvals; and
- Reviewing annual safety and engineering cases for the deferral of removal for internal examination of crane slew ring bearings and provision of such a certificate.

To fulfill these obligations, the verification company makes regular visits to the offshore installations pertaining to the contract of work. The skills and competence of the surveyors are aligned to the type of work being undertaken. In other words, one platform visit might be tailored toward instrumentation, and another visit might concentrate on pressure systems, and the surveyor in each case would be trained and competent in the appropriate discipline. An offshore visit will generally last several days (and nights) and will include such things as witnessing function tests and reviewing records that will demonstrate that the duty holder is assuring the suitability of the SCEs. Note that the duty holder places a contract with the verification company. Annual summary reports are issued as well as individual discipline reports. When HSE engineers carry out their offshore visits, one of the first things they ask to see is the verification report.

HSE also carries out offshore and onshore inspections and audits. A typical offshore visit involves a focal point plus up to four specialist HSE engineers and typically lasts between 5 and 7 days (and nights—note that the duty holder is responsible for transporting the HSE engineers to the installation and for providing messing facilities. This is not considered to be a conflict of interest issue, as all operators have to comply). The aim is to visit each installation annually. Note that in this example, an installation will be a platform that was designed to produce 80,000 to 200,000 barrels of oil per day (although current production is likely to be much less than this). The HSE inspectors will be highly qualified discipline engineers (degree or equivalent) and will be chartered engineers, the UK equivalent of the professional engineer. During the offshore visits, they perform tasks such as witnessing function tests, fire pump tests, and electrostatic discharge tests. They also carry out general visual inspections and audit offshore records.

HSE also carries out onshore audits of the duty holder's office. These audits focus on a review of the duty holder's records, how it is managing and maintaining the SCEs and, if there is a backlog of work, what plans are in place to address that backlog. In recent years, HSE has instigated key programmes (KPs) to try to determine how the duty holders are addressing the management of the SCEs. This year, KP4 is addressing Ageing Assets and Life Extension Programmes.[13]

Note that, although there is a legal requirement for a duty holder to employ a verification body, there is no communication link between HSE and the verification companies. That is, all communication is via the duty holder, so if HSE wishes to see the verification reports, the reports are requested from the duty holder and not the verification company.

COMPLETING THE COMMITTEE'S STUDY

In carrying out the remainder of its study, the committee will continue to gather information to evaluate the auditing methods, the entities that could perform the audits, and the roles and qualifications of the auditors and inspectors presented in this report. The committee will also examine new regulations that are being discussed (e.g., SEMS Rule II) and other initiatives (of both governmental and private organizations) that are being developed to respond to the SEMS final rule for U.S. OCS oil and gas operations. All of

[13] See HSE, http://www.hse.gov.uk/offshore/ageing/kp4-programme.htm.

these activities are intended to inform the committee's deliberations for its final report, due later in 2011 following release of the final report of the NAE/NRC Committee for the Analysis of Causes of the *Deepwater Horizon* Explosion, Fire, and Oil Spill to Identify Measures to Prevent Similar Accidents in the Future. The committee's report will recommend a method for assessing the effectiveness of an operator's SEMS program for any given offshore drilling or production facility, taking into account the findings and recommendations of the NAE/NRC committee.

Sincerely,

Kenneth Arnold
Chair, Committee on the Effectiveness of Safety and Environmental Management Systems for Outer Continental Shelf Oil and Gas Operations

Appendix A

Committee on the Effectiveness of Safety and Environmental Management Systems for Outer Continental Shelf Oil and Gas Operations

COMMITTEE

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Stuart Jones, Lloyd's Register EMEA, Aberdeen, Scotland, United Kingdom

Thomas Kitsos, Consultant, Bethesda, Maryland

Frank J. Puskar, Energo Engineering, Houston, Texas

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Appendix B

Biographical Information on the Committee on the Effectiveness of Safety and Environmental Management Systems for Outer Continental Shelf Oil and Gas Operations

Kenneth E. Arnold, National Academy of Engineering, *Chair,* is an independent consultant with more than 45 years of experience in projects, facilities, and construction related to upstream oil and gas development. He spent 16 years at Shell in engineering and engineering and research management prior to forming Paragon Engineering Services, a project management and offshore engineering company, in 1980; it had a staff of 600 when it was sold to AMEC in 2005. Mr. Arnold is the author, coauthor, or editor of several textbooks and numerous technical articles on the design and project management of production facilities. He taught production facility design at the University of Houston and has been active in the Society of Petroleum Engineers (SPE) and other technical societies. He was named Houston's 2003 Engineer of the Year by the Texas Society of Professional Engineers, and is the recipient of the SPE Public Service Award and the DeGolyer Distinguished Service Medal. He was elected to the National Academy of Engineering in 2005, primarily for the work he has done in promoting offshore safety. Mr. Arnold has served on two Marine Board committees, including the 1990 Committee on Alternatives for Offshore Inspection, and was a member of the Marine Board for 6 years. He currently works as a senior technical advisor for WorleyParsons and as an independent consultant for the American Bureau of Shipping (ABS), oil and gas companies, and contractors on an as-needed basis.

J. Ford Brett is Managing Director of PetroSkills and Chief Executive Officer of Oil and Gas Consultants International (OGCI), the world's largest petroleum training organization. Mr. Brett has consulted in more than 25 countries worldwide in the area of petroleum project and process management. Prior to joining OGCI, he was with Amoco Production Company, where he worked on drilling projects in the Bering Sea, the North Slope of Alaska, the Gulf of Mexico, offshore Trinidad, and Wyoming. In 2000, the American Society for Competitiveness awarded him the Crosby Medallion for Global Competitiveness for work in "global competitiveness through quality in knowledge management, best practices transfer, and operations improvement." He currently serves on the Society of Petroleum Engineers (SPE) Board as Technical Director for Drilling and Completion. For his work on improved drilling techniques, he was also honored in 1996 with a nomination for the National Medal of Technology, the U.S. government's highest technology award. Mr. Brett has been granted more than 25 U.S. and international patents and has authored or coauthored more than 25 technical publications. He holds a BS degree in mechanical engineering and physics from Duke University, an MSE from Stanford University, and an MBA from Oklahoma State University.

Paul S. Fischbeck is Professor in the Department of Engineering and Public Policy and the Department of Social and Decision Sciences at Carnegie Mellon University. He is also Director of Carnegie Mellon's Center for the Study and Improvement of Regulation (CSIR), where he coordinates a diverse research group exploring all aspects of regulation, from historical case studies to transmission-line siting to emissions-trading programs. Widely published, Dr. Fischbeck has served on a number of national research committees and review panels, including the National Research Council (NRC)–Transportation Research Board (TRB) Committee on School Transportation Safety; the National Science Foundation's Decision, Risk, and Management Sciences Proposal Review Committee and Small Business Innovative Research Proposal Review Committee; the NRC–TRB Committee on Evaluating Double Hull Tanker Design Alternatives; and the NRC–TRB Committee on Risk Assessment and Management of Marine Systems. His research involves normative and descriptive risk analysis, including development of a risk index to prioritize inspections of offshore oil production platforms; an engineering and economic policy analysis of air pollution from international shipping; a large-scale probabilistic risk assessment of the space shuttle's tile protection system; and a series of expert elicitations involving a variety of topics, including environmental policy selection, travel risks, and food safety. He is cofounder of the Brownfields Center at Carnegie Mellon, an interdisciplinary research group investigating ways to improve industrial site reuse. He is involved with a number of professional research organizations, including the American Society for Engineering Education, the Institute for Operations Research and Management Sciences, the Military Operations Research Society, and the Society of Risk Analysis. He has chaired a National Science Foundation panel on Urban Interactions and currently serves on the Environmental Protection Agency's Science Advisory Board. He holds a BS in architecture from the University of Virginia, an MS in operations research and management science from the Naval Postgraduate School, and a PhD in industrial engineering and engineering management from Stanford University.

Stuart Jones is a project manager with Lloyd's Register EMEA, Aberdeen, Scotland, United Kingdom, where he is responsible for several integrity management contracts for clients operating oil and gas installations in the North Sea. He started offshore work in the oil and gas industry in 1983, when he joined Conoco in Aberdeen as its maintenance coordinator for corrosion, responsible for fabric maintenance, inspection, and corrosion monitoring on the Murchison and Hutton tension leg platforms. He was Corrosion and Inspection Engineer for the British Gas Rough Field operation between 1990 and 1995, when he left to follow a career more aligned with risk-based inspection. He has performed risk-based inspection studies on oil and gas installations and their associated pipelines both on shore and off shore. In 2000 he joined Lloyd's Register, and since then has performed a number of roles, including senior corrosion engineer, team leader, project manager, and now project controls manager. In 2009, at the initiation of this committee study, he was on a long-term international assignment with Lloyd's Register Capstone, initially as head of their Upstream Operations Team and later as head of their project controls group. He returned to work in the United Kingdom in October 2010. Mr. Jones has published a number of papers and made numerous presentations on corrosion and risk-based inspection, and from 2008 to 2010 he served on the SPE's Gulf Coast Section, Projects, Facilities, and Construction Study Group. Mr. Jones earned a second-class honours degree in metallurgy from the University College of Swansea, Wales, United Kingdom, in 1974. He is a professional member of the Institute of Corrosion and of the Institute of Materials, Minerals, and Mining and is a chartered engineer.

Thomas Kitsos served as Executive Director of the U.S. Commission on Ocean Policy (USCOP) from 2001 to 2004. In 2005, Dr. Kitsos retired from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, as Associate Deputy Assistant

Administrator for Ocean Services. He is currently a private consultant on national ocean policy, advising the Joint Ocean Commission Initiative, the follow-up, foundation-supported organization composed of the members of USCOP and the privately funded Pew Ocean Commission and dedicated to promoting ocean policy reform proposals recommended by the two commissions. His earlier experience included 6 years at the Department of the Interior (DOI), where his primary responsibilities were in the area of energy development on the Outer Continental Shelf. He also served as Special Assistant to the Assistant Secretary, Land and Minerals Management, and as DOI's Acting Director of the Minerals Management Service, among other positions. Prior to his tenure at DOI, Dr. Kitsos spent 20 years on Capitol Hill on the staff of the U.S. House of Representatives' Committee on Merchant Marine and Fisheries. His final position with the committee was as chief counsel, advising the chairman on national ocean and coastal issues, offshore energy development, and environmental and other marine management legislation, including amendments to the Outer Continental Shelf Lands Act and the Coastal Zone Management Act. He holds BS degrees in education and social science from the Eastern Illinois University, and an MA and PhD in political science from the University of Illinois.

Frank J. Puskar is Managing Director of Energo Engineering in Houston, Texas. Energo specializes in advanced structural engineering and structural integrity management (SIM) of existing offshore structures. Mr. Puskar has more than 28 years of experience in the offshore industry and is a recognized leader in SIM technology. He has been involved in the planning of above-water and below-water inspections and structural assessments for more than 250 fixed and floating platforms located worldwide. He has served on committees or task groups of the American Petroleum Institute (API), International Standards Organization (ISO), and American Society of Civil Engineers and on the Offshore Operators Committee and was Chairman of the API Task Group that developed API Bulletin 2HINS, *Guidance for Post-hurricane Structural Inspection of Offshore Structures,* published in May 2009. In 2007, he was awarded the Minerals Management Service Corporate Leadership Award for his industry efforts, including improving codes and standards related to the damage and destruction of platforms in the Gulf of Mexico from Hurricanes Ivan, Katrina, and Rita. He earned a master of engineering degree in ocean engineering from the University of California, Berkeley, and a BS in civil engineering from the State University of New York at Buffalo. He is a registered professional engineer in California, Louisiana, and Texas.

Darin W. Qualkenbush has served in the U.S. Coast Guard (USCG) for 22 years and is currently serving in the National Technical Advisor office of the Outer Continental Shelf National Center of Expertise in Morgan City, Louisiana. This office is responsible for revitalizing the technical competency and expertise within the USCG marine safety program to keep pace with the growth and complexity of the offshore maritime industry. Additional duties include directing the generation of regulations, policy, and doctrine for marine safety and offshore operations, as well as being a repository for USCG expertise and best practices for the offshore oil and gas industry. LT Qualkenbush's previous assignment was as Chief, Outer Continental Shelf Inspections, at the Marine Safety Unit, Morgan City, where he was responsible for all regulatory and compliance issues for exploration, exploitation, and production of oil and natural gas within USCG's approximately 69,000-square-mile offshore area of responsibility. He is a subject matter expert on lifesaving and firefighting equipment and deployment and on USCG regulatory compliance and International Maritime Organization Convention compliance on offshore oil and gas production platforms, offshore drilling units, and oil field support vessels of all types.

Raja V. Ramani, National Academy of Engineering, is emeritus George H., Jr., and Anne B. Deike Chair of Mining Engineering and Professor Emeritus of Mining and Geo-environmental Engineering at The Pennsylvania State University. Dr. Ramani holds MS and PhD degrees in mining engineering from Penn State, where he has been on the faculty since 1970. He is a certified first-class mine manager under the Indian Mines Act of 1952 and has been a registered professional engineer in the Commonwealth of Pennsylvania since 1971. Dr. Ramani's research activities include mine health, safety, productivity, environment, and management; flow mechanisms of air, gas, and dust in mining environs; and innovative mining methods. Dr. Ramani has been a consultant to the United Nations, World Bank, National Safety Council, mining companies, and governmental agencies. He has published extensively on health, safety and environmental planning, and management issues and has received numerous awards from academia and technical and professional societies. He was the 1995 president of the Society for Mining, Metallurgy, and Exploration (SME). Dr. Ramani has served on the U.S. Department of Health and Human Services' Mine Health Research Advisory Committee (1991 to 1998). He was the chair of the National Research Council (NRC) Committee on Post Disaster Survival and Rescue (1979 to 1981) and a member of the Health Research Panel of the NRC Committee on the Research Programs of the U.S. Bureau of Mines (1994). He was a member of the Department of the Interior's Advisory Board to the Director of the U.S. Bureau of Mines (1995) and a member of the Secretary of Labor's Advisory Committee on the Elimination of Coal Worker's Pneumoconiosis (1995 to 1996). More recently, he was a member of the NRC Panel on Technologies for the Mining Industries (2000 to 2001), the NRC Committee on Coal Waste Impoundment Failures and Breakthroughs (2001 to 2002), the NRC Committee to Inform Coal Policy (2005 to 2007), and the NRC Committee to Develop the Framework for the Evaluation of NIOSH [National Institute of Occupational Safety and Health] Research Programs (2005 to 2009) and was chair of the National Academy of Sciences Committee to Evaluate the NIOSH Mining Health and Safety Research Program (2005 to 2007). In 2002, he chaired the Pennsylvania Governor's Commission on Abandoned Mine Voids and Mine Safety that was set up immediately after the Quecreek Mine inundation incident and rescue. Dr. Ramani is a distinguished member of SME (class of 1988) and an honorary member of the American Institute of Mining, Metallurgical, and Petroleum Engineers (class of 2010).

Vikki Sanders is a human factors consultant for Atkins Global in Houston, Texas, and works on a variety of oil and gas projects, providing human factors assessments of control rooms and other equipment for offshore platforms. She also provides input to the safety management system integration toolkit for the marine industry. Previous clients include BP, Shell, Hess, and the American Bureau of Shipping (ABS). Ms. Sanders graduated in psychology with honors in 1995 from the University of Humberside, United Kingdom, and earned a master's degree in organizational psychology from the University of Nottingham, United Kingdom, in 2002. After receiving her master's degree, she began working in organizational development at the Aston Centre for Effective Organisations, Birmingham, United Kingdom, focusing on leadership, teamwork, and employee satisfaction, before working in safety management and human factors at the Health and Safety Laboratory, an agency of the Health and Safety Executive (HSE), the regulatory body in the United Kingdom. She provided technical assistance to HSE inspectors, focusing on assessment of workforce tasks in multiple industries in the United Kingdom.

Appendix C

Statement of Task

This project will recommend a method for assessing the effectiveness of an operator's Safety and Environmental Management System (SEMS) on any given offshore drilling or production facility. In addition, the committee will prepare a brief interim report in April 2011 that will provide a listing of potential methods for assessing effectiveness along with the pros and cons of each method as they are known to that point. The committee will address methods to maximize the implementation effectiveness of individual SEMS rather than the adequacy of the Final Rule of October 2010 requiring SEMS to mitigate safety and environmental risk of offshore platform operations.

The committee's assessment of effective methods will focus on the safety and environmental risks of offshore production until after the release of the report of the NAE/NRC Committee for the Analysis of Causes of the *Deepwater Horizon* Explosion, Fire, and Oil Spill to Identify Measures to Prevent Similar Accidents in the Future, which is expected in June 2011. The committee's assessment of effective methods for safety and environmental risks of exploration drilling will take into account the findings and recommendations of the NAE/NRC committee.

The project is sponsored by the Bureau of Ocean Energy Management, Regulation, and Enforcement (formerly the Minerals Management Service) of the U.S. Department of the Interior.

Appendix D

Review of the Document

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that assist the authors and NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The following individuals participated in the review of this report: Baruch Fischhoff, Carnegie Mellon University, Pittsburgh, Pennsylvania; David A. Hofmann, University of North Carolina, Chapel Hill; Morgan L. Jones, PetroSkills, Tulsa, Oklahoma; Paul L. Kelly, Energy and Ocean Policy Consultant, Houston, Texas; Joshua D. Reynolds, U.S. Coast Guard, Washington, D.C.; and Stanley C. Suboleski, Virginia Polytechnic Institute and State University (retired), Blacksburg. Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the committee's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Hyla S. Napadensky, Napadensky Energetics, Inc. (retired), Grand Marais, Minnesota; and C. Michael Walton, University of Texas, Austin. Appointed by NRC, they were responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Appendix E

Acronym List

ABS	American Bureau of Shipping
ALARP	as low as reasonably practicable
API	American Petroleum Institute
BOEM	Bureau of Ocean Energy Management
BOEMRE	Bureau of Ocean Energy Management, Regulation, and Enforcement
BSEE	Bureau of Safety and Environmental Enforcement
CSIR	Center for the Study and Improvement of Regulation
DOI	Department of the Interior
HSE	Health and Safety Executive
I3P	independent third party
INC	incident of noncompliance
ISO	International Standards Organization
JIP	joint industry project
KP	key programme
KPI	key performance indicators
MMS	Minerals Management Service
MOC	management of change
MSHA	Mine Safety and Health Administration
NAE	National Academy of Engineering
NRC	National Research Council
OCS	Outer Continental Shelf
OGCI	Oil and Gas Consultants International
ONRR	Office of Natural Resources Revenue
OSHA	Occupational Safety and Health Administration
PINC	potential incident of noncompliance
PSM	process safety management
QRA	quantitative risk assessment

RP	recommended practice
SAMS	Safety Assessment of Management Systems
SCE	safety-critical element
SEMP	Safety and Environmental Management Program
SEMS	Safety and Environmental Management Systems
SIM	structural integrity management
SME	Society for Mining, Metallurgy, and Exploration
SPE	Society of Petroleum Engineers
TRB	Transportation Research Board
UK	United Kingdom
USCG	United States Coast Guard
USCOP	U.S. Commission on Ocean Policy
VR	virtual reality