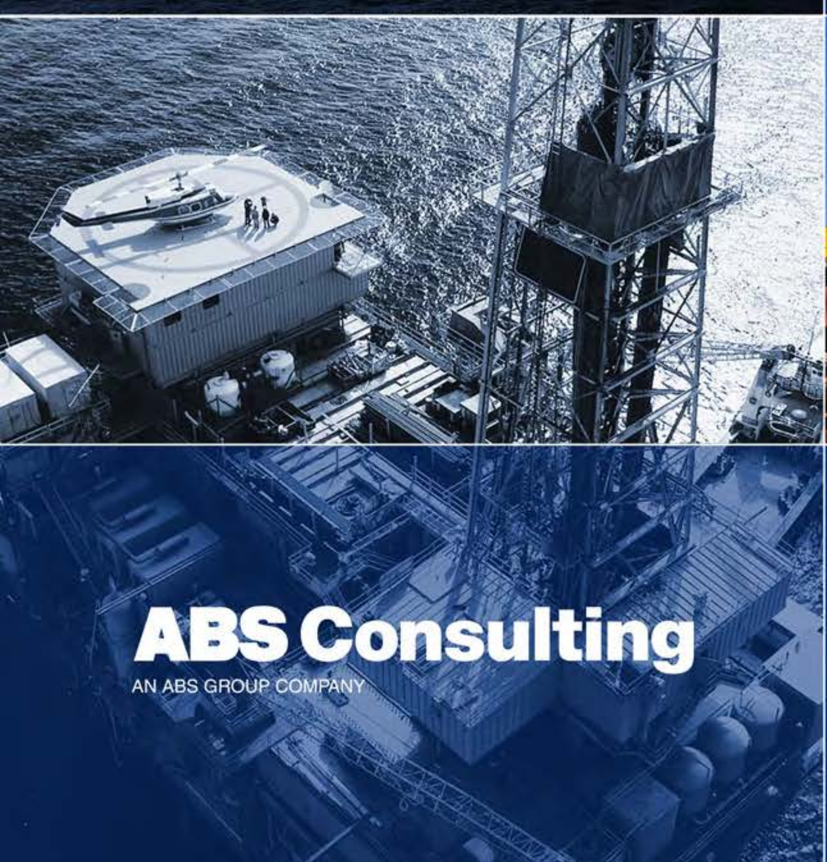
Evaluation of the Collection and Application of Risk Data

Final Summary Report

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

Submitted by
ABSG CONSULTING INC.
1525 Wilson Blvd., Suite 625
Arlington, VA 22209
(703) 351-3700

September 9, 2015



ABS Consulting
AN ABS GROUP COMPANY

BPA Contract # E13PA00008
Task Order # E14PB00079
Deliverable E

Executive Summary

Project Objectives

The Bureau of Safety and Environmental Enforcement (BSEE) is committed to proactively identifying, analyzing, communicating, and managing risks related to outer continental shelf (OCS) oil and gas exploration and production activities. For decades, BSEE and its predecessor, the Mineral Management Service (MMS), have been dedicated to overseeing these activities to ensure safe and clean operations. During these years, BSEE has developed a good understanding of the unique risks posed by OCS activities and the measures that can be employed to manage those risks to acceptable levels. While this knowledge provides a strong foundation, BSEE lacks an operational risk management program that enables systematic, transparent, auditable, and goal-focused management of risks. Toward that end, in September 2014, BSEE awarded the *Evaluation of the Collection and Application of Risk Data* contract to ABS Consulting, who assembled an evaluation team made up of risk experts from the United States (U.S.), United Kingdom (UK), and Norway to achieve the following objectives:

1. Conduct a meta-study of how other international and U.S. regulators collect and use risk data
2. Recommend risk methodologies for application to key BSEE decision-making processes
3. Develop a concept for a BSEE operational risk management program
4. Provide a high-level implementation plan for the first few years of the program

Need for Formalized Risk Management

BSEE is focused on the reduction of offshore risk… Part of managing risk is monitoring the trends we are seeing offshore, and gauging the effectiveness of our approach. This not only provides a valuable perspective on risks, it helps direct our future efforts. Moreover, information of this nature needs to be shared among all stakeholders, so that we have a common appreciation for the progress that has been made as well as the challenges ahead.

Director Salerno, Annual Report 2014

The proper application of risk analysis techniques can develop useful information about the likelihoods and consequences of a spectrum of unwanted outcomes into an inclusive, orderly structure to help decision makers make better choices about their organization's activities to help reduce risks. Risk identification and assessment cover a wide range of approaches from simple screening methods, to quite sophisticated quantitative modeling. The key to finding the best approach is to match the level of modeling sophistication to the level of information needed by decision makers. This can be accomplished by leveraging historical experience and expert judgment through the application of sound analytical methods.

Risk management is the process to identify and manage the estimated impact of uncertain events toward acceptable levels. The recommended risk management cycle by the Government Accountability Office (GAO)[1] is made up of five phases: (1) setting strategic goals, objectives, and determining constraints; (2) assessing the risks; (3) evaluating alternatives for addressing these risks; (4) selecting the

[1] Government Accountability Office; PROTECTION OF CHEMICAL AND WATER INFRASTRUCTURE Federal Requirements, Actions of Selected Facilities, and Remaining Challenges, March 2005, GAO-05-327

appropriate alternatives; and (5) implementing the alternatives and monitoring progress. This cycle, while generic, provides a useful framework for developing and implementing risk management processes and programs.

Unique Challenges

BSEE has a number of unique challenges in systematically analyzing and managing risk:

- **Dynamic Industry** – Regulated industry is continuing to apply new technologies and migrate into more extreme operating environments (e.g., deep water, high pressure, Arctic)
- **Rare, Catastrophic Risks** – Risks for many scenarios are dominated by rare, catastrophic events, making historical incident analysis of limited utility for predicting future risks
- **Highly Complex Systems** – OCS oil and gas exploration and production operations are highly complex systems relying on a mix of engineered safeguards and human actions
- **Multiple Scenarios of Concern** – BSEE seeks to prevent a broad array of safety and environmental accidents, including: fires, explosions, blowouts, and dropped objects
- **Industry Reporting** – BSEE currently does not require industry reporting as comprehensively as other agencies, particularly in the areas of equipment reliability and near misses
- **BSEE Data Taxonomy** – The specific data fields captured within BSEE enterprise systems are insufficient to support more complex risk modeling techniques
- **Large Regulated Community** – With ~3000 regulated platforms, BSEE has a much larger community to oversee compared to many other agencies

Other Agency Risk Management Programs

The evaluation team, with guidance from BSEE experts in the Office of Offshore Regulatory Programs (OORP), identified and performed preliminary research on 20 international and U.S. government agencies. The team then performed an in-depth review on a subset of these agencies with established risk management programs most relevant to BSEE, as shown in Table E1.

Table E1. International and U.S. Agencies Reviewed

International Agencies	U.S. Agencies
✓ **Health & Safety Executive (HSE): *United Kingdom*** ✓ **Petroleum Safety Authority (PSA): *Norway*** - National Offshore Petroleum Safety & Environmental Management Authority (NOPSEMA): *Australia* - Agencia Nacional do Petroleo (ANP): *Brazil* - Canada-Newfoundland Offshore Petroleum Board (C-NLOPB) & Canada-Nova Scotia Offshore Petroleum Board (C-NSOPB) - Danish Energy Agency (DEA) - European Commission: *European Union* - Comision Nacional de Hidrocarburos (CNH): *Mexico* - State Supervision of Mines (SSM): *Netherlands* - Department of Labour & WorkSafe NZ: New Zealand	✓ **Mine Safety & Health Administration (MSHA)** ✓ **National Aeronautics and Space Administration (NASA)** ✓ **Nuclear Regulatory Commission (NRC)** ✓ **United States Coast Guard (USCG)** - Department of Energy (DOE) - Department of Transportation (DOT) - Environmental Protection Agency (EPA) - Federal Aviation Administration (FAA) - Food and Drug Administration (FDA) - Occupational Safety and Health Administration (OSHA)

✓ **Selected for in-depth review**

The other agencies' risk management programs represent a variety of philosophies and, while the wholesale adoption of one of the agency programs documented is not recommended for BSEE due to differences in organizational cultures, missions, hazards, and operating environments, lessons can still be learned to develop a successful program within BSEE. Specifically, the evaluation team identified attributes about select risk management programs that could be emulated by BSEE (Table E2).

Table E2. Key Attributes of Select Other Agency Risk Management Programs

Agency	Key Attributes
PSA	*Trends in Risk Level in the Petroleum Activity (RNNP)* is an annual strategic assessment that is valuable for establishing priorities and communicating with industry
USCG	*National Maritime Strategic Risk Assessment (NMSRA)* provides a high-level understanding of risk across the USCG mission set that is applied to numerous strategic decisions
NASA	*Accident Precursor Analysis (APA)* program is a model for screening risks, identifying precursors, developing a risk inventory, and cutting across operational silos
NRC	*Risk-Informed Regulations and Inspections Program* demonstrates the "gold standard" for comprehensive operational risk management programs
HSE	*Safety Case* represents an alternative to government-led risk management that puts the onus on industry to design and demonstrate that its operations are within society's risk tolerance thresholds

Vision of a BSEE Operational Risk Management Program

BSEE currently performs a number of risk management functions. Incident reporting keeps BSEE aware of the incidents and accidents offshore. The BSEE *Risk-based Inspection Prioritization* project provides a means for targeted utilization of inspection resources, and the development of regulations is informed through an implicit understanding of risk. While each of these processes involves risk management, they are currently conducted in a largely independent and ad hoc manner, where data analysis techniques are not consistently applied and lessons are not shared among the processes. As illustrated in Figure E1, the evaluation team recommends that BSEE evolve from the current state of ad hoc risk management to a comprehensive operational risk management program to enable it to proactively identify, communicate, and manage risks related to incidents that may result in unwanted safety and environmental consequences. The program would apply the best available information through aligned risk management tools to generate outputs to support regulatory, permitting, and inspection-related decisions.

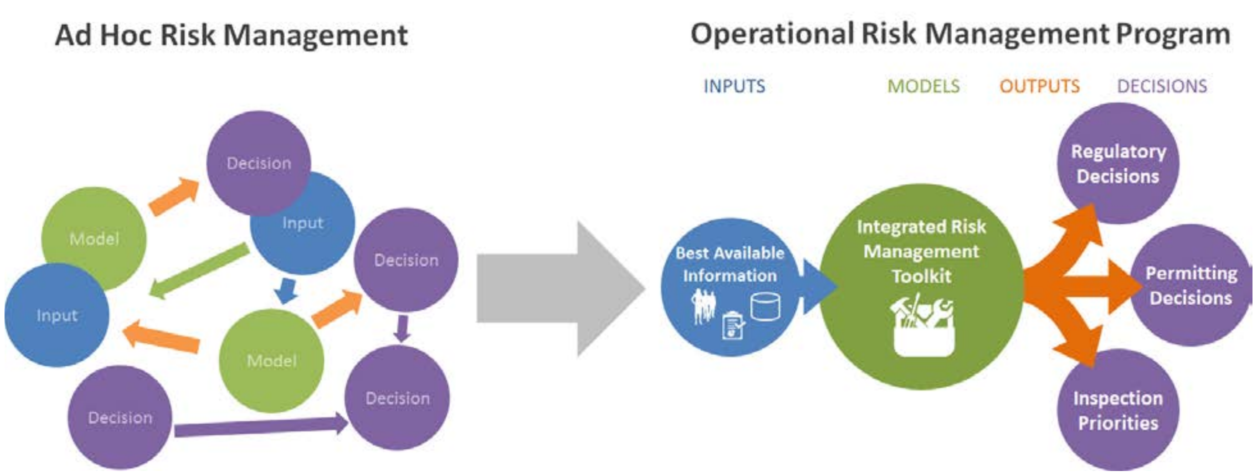


Figure E1. Evolution of BSEE Risk Management

Figure E2 illustrates the key elements of this operational risk management program concept, including the flow of information from inputs to risk models to generate outputs that support decisions. It also illustrates the functions to be performed by the various OORP branches and sections.

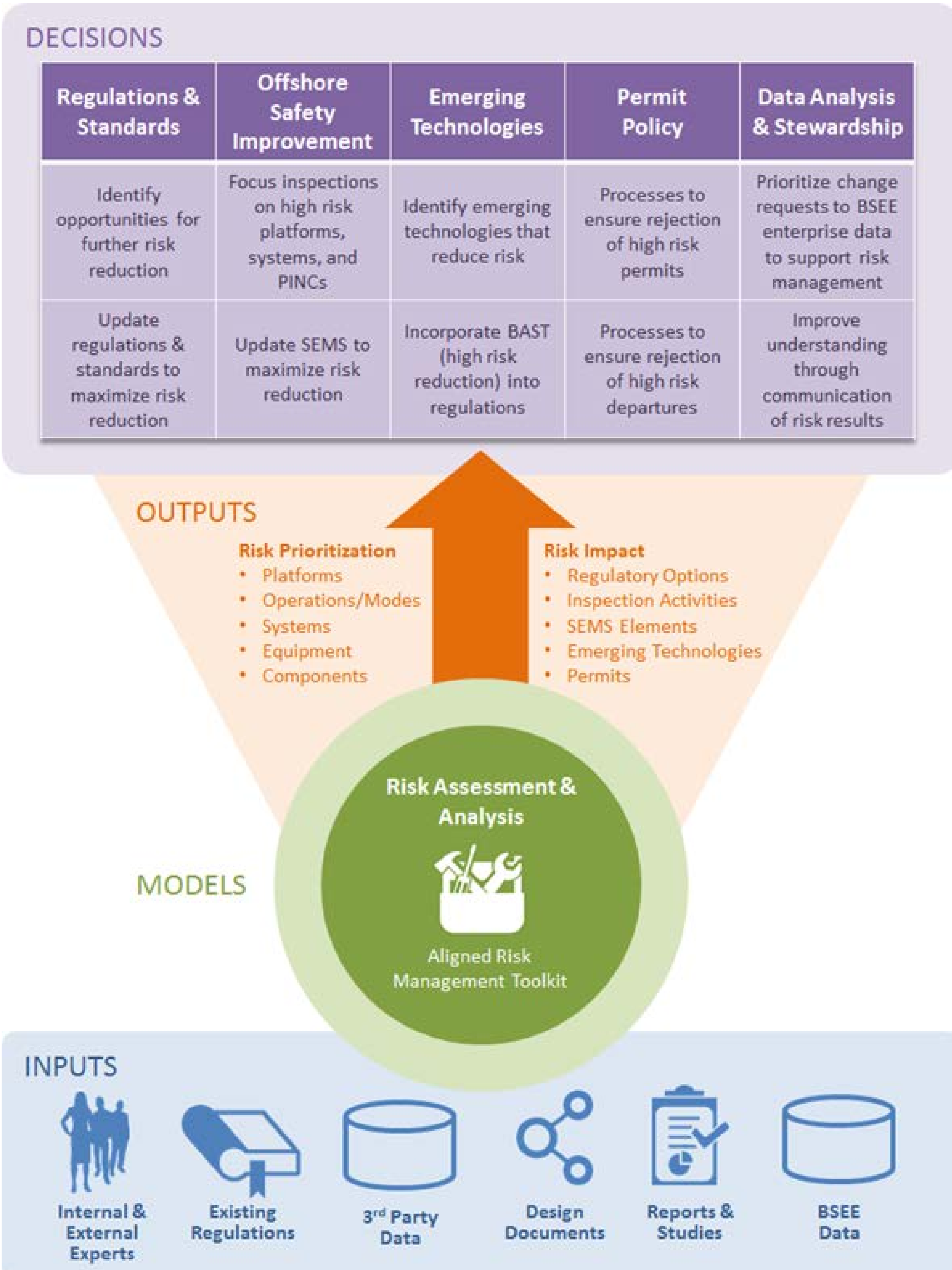


Figure E2. Implementation of the Operational Risk Management Program Within the OORP

The key characteristics of a fully mature operational risk management program, as illustrated in Figure E2, includes:

- ✓ Providing a centralized risk management function that ensures that methodologies are aligned with one another and compliant with best practices
- ✓ Facilitating all phases of the risk management cycle
- ✓ Providing a core risk management team with detailed risk modeling expertise capable of tapping into niche technical expertise across BSEE to facilitate risk analysis and management activities
- ✓ Training personnel to ensure staff has the required competencies to support the program
- ✓ Implementing and maintaining the appropriate risk management tools required by the program
- ✓ Making use of the best available information and identifying enterprise data requirements to address data gaps and improve data quality
- ✓ Optimizing analytical effort spent on an issue based on the issue's assessed risk and certainty
- ✓ Generating outputs with sufficient accuracy, precision, and relevance to support key decisions
- ✓ Intuitively communicating risk information by leveraging cutting edge data visualization techniques and tools

Implementation Plan

Developing a mature operational risk management program that provides useful information to support strategic decision making does not occur overnight; rather, it requires a long-term commitment to achieve the desired end state. In the design of the program, it is essential to understand that the requirements of the system will evolve over time, based on a number of influencing factors such as:

- Changing leadership priorities
- Altering regulatory philosophy
- Shifting political landscape or changing societal acceptance of OCS oil and gas risks
- Supporting new decision-making processes with risk information
- Improving breadth and quality of available internal and external data
- Increasing computing power and modeling capabilities, enabling employment of more sophisticated risk modeling techniques

For this fluid environment, the evaluation team identified a collection of widely regarded risk methods to serve as toolkit from which BSEE can generate tailored risk information to support decisions while ensuring alignment across the efforts. This sound foundation addresses currently identified needs while providing agility to change courses to meet new challenges. The evaluation team then developed a high-level implementation plan based on (1) desirable attributes of the other agency programs, (2) previous experience in developing similar programs for other organizations, and (3) an understanding of the unique aspects of BSEE's mission, organization, decision support needs, available data, and analytical resources. The design of the program is built upon five guiding principles.

Guiding Principles

1. Establish a strong foundation for good decision making
2. Start small and get smarter over time
3. Focus analytical resources on highest risk issues
4. Provide flexibility to meet evolving decision-making demands
5. Perfect is the enemy of good – provide <u>timely</u> and useful risk information

The evaluation team proposes developing the program through annual analytic cycles, as illustrated in Figure E3, for the first 2+ years. The foundation of the cycle is an annual *OCS Strategic Risk Profile*, which would: (1) provide a common understanding of risk spanning BSEE's responsibilities, (2) identify issues for moderate and complex risk modeling, (3) identify new/enhanced enterprise data requirements, and (4) provide the foundation for risk-based decision support.

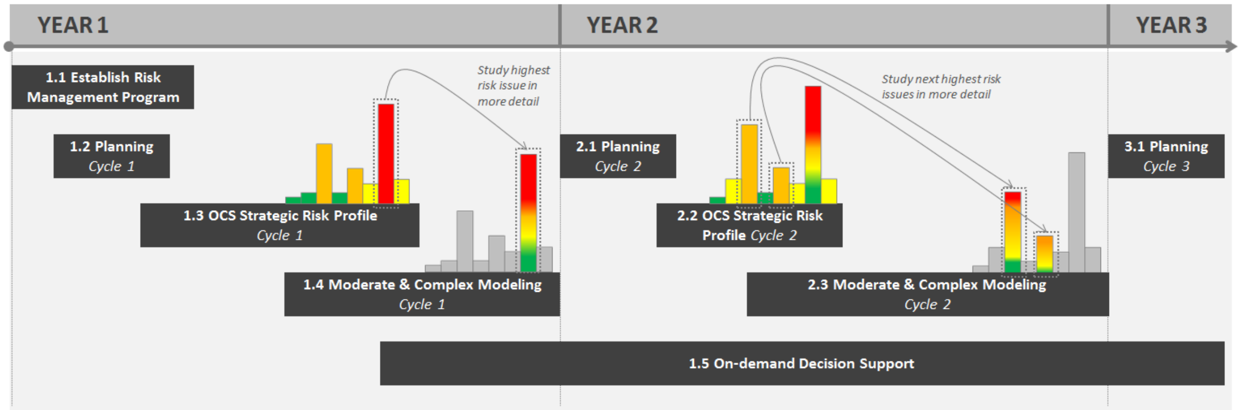


Figure E3. Recommended High-level Implementation Plan (Years 1 and 2+)

The key phases for Year 1 are:

1. **Establish Risk Management Program.** Develop a foundation for the implementation and long-term evolution by establishing key facets of a successful program, including: organization, policy, processes, methods, tools, and performance measures.
2. **Planning.** Plan for the first cycle of the risk management program by defining the desired outputs, budget, timelines, milestones, resources, and potential roadblocks.
3. **OCS Strategic Risk Profile.** Perform a strategic, baseline risk analysis to develop a high-level understanding of risks spanning BSEE's mission set. Leverage the best available inputs using simple risk analysis methods to generate risk information to support strategic planning, regulatory development/analysis, inspection priorities, permitting, etc.
4. **Moderate & Complex Modeling.** Develop a better understanding of select high risk and high uncertainty issues (from Phase 3) through more complex risk modeling.
5. **On-demand Decision Support.** Apply the results of risk information generated in Phases 3 and 4 to improve decision making throughout the organization. Provide an ongoing and on-demand risk management technical support function to OORP.

Each annual cycle will include the major phases described for the first year with the exception of the *Establish Risk Management Program* task. At the start of each annual cycle, the risk management team will plan for the annual cycle based on demand for increased decision support, lessons learned from previous cycles, and new/enhanced inputs, such as newly available enterprise data. With each annual cycle, BSEE risk information will increase in quality and scope.

Table of Contents

List of Tables

List of Figures

Acronyms

ACRI	Anomalous Condition Risk Importance
ALARP	As Low As Reasonably Practicable
ANP	Agencia Nacional do Petroleo
APA	Accident Precursor Analysis
BARD	Boating Accident Reporting Database
BOE	Barrel of Oil Equivalent
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
BTS	Bureau of Transportation Statistics
CBA	Cost Benefit Analysis
CCF	Common Cause Failure
CCFDB	Common Cause Failure Database
CCI	Conditional Consequence Index
CDF	Core Damage Frequency
CNH	Comision Nacional de Hidrocarburos
C-NLOPB	Canada-Newfoundland Offshore Petroleum Board
C-NSOPB	Canada-Nova Scotia Offshore Petroleum Board
CODAM	Corrosion and Damage Database
CPF	Cost of Preventing a Fatality
CSB	Chemical Safety Board
DDRS	Daily Drilling Report System
DEA	Danish Energy Agency
DFU	Defined Hazard and Accident Conditions
DOE	Department of Energy
DOT	Department of Transportation
DSA	Documented Safety Analysis
ED	Energy Division
EPA	Environmental Protection Agency
EPIX	Equipment Performance Information Exchange System
ETA	Event Tree Analysis
EU	European Union
FAA	Federal Aviation Administration
FCI	Failure Condition Index
FDA	Food and Drug Administration
FMEA	Failure Modes and Effects Analysis
FMECA.	Failure Modes, Effects, and Criticality Analysis
FSSI	Fish Stock Sustainability Index
FTA	Fault Tree Analysis
GAO	Government Accountability Office
GoM	Gulf of Mexico
GPRA	Government Performance Reporting Act

HAZOP	Hazard and Operability
HFIS	Human Factors Information System
HID	Hazardous Installations Directorate
HS&W Act	Health and Safety At Work Act of 1974
HSE	Health & Safety Executive
INCs	Incidents of Non-Compliance
INL	Idaho National Laboratory
INPO	Institute of Nuclear Power Operations
IRF	International Regulators' Forum
IRPA	Individual Risk per Annum
LERF	Large Early Release Frequency
LERs	Licensee Event Reports
LOCA	Loss-of-Coolant Accident
LOPA	Layer of Protection
MBIE	Ministry of Business, Innovation and Employment
MISLE	Marine Information For Safety & Law Enforcement
MMS	Mineral Management Service
MSHA	Mine Safety & Health Administration
MSRAM	Maritime Security Risk Analysis Model
NASA	National Aeronautics and Space Administration
NMSRA	National Maritime Strategic Risk Assessment
NOAA	National Oceanic and Atmospheric Administration
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NPD	Norwegian Petroleum Directorate
NPRDS	Nuclear Plant Reliability Data System
NRC	Nuclear Regulatory Commission
OCS	Outer Continental Shelf
OGA	Other Government Agency
OORP	Office of Offshore Regulatory Programs
OREDA	Offshore Reliability Data
OSHA	Occupational Safety and Health Administration
PEMEX	Mexican Petroleum
PF	Proportionality Factor
PINCs	Potential Incidents of Non-Compliance
PLL	Potential Loss of Life
PoB	People on Board
PRA	Probabilistic Risk Assessment
PrRA	Preliminary Risk Analysis
PSA	Petroleum Safety Authority
QRA	Quantitative Risk Assessment
R2P2	Reducing Risks, Protecting People
RADS	Reliability & Availability Data System
RAW	Risk Achievement Worth

RBDM	Risk-Based Decision-Making
RCM	Reliability-Centered Maintenance
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
RIN	Risk Index Number
RMP	Risk Management Plan
RNNP	Trends in Risk Level in the Petroleum Activity
RRW	Risk Reduction Worth
SAPHIRE	Systems Analysis Programs for Hands-On Integrated Reliability Evaluations
SCSS	Sequence Coding and Search System
SEMS	Safety and Environmental Management Systems
SFAIRP	So Far As Is Reasonably Practical
SME	Subject Matter Expert
SPAR	Standardized Plant Analysis Risk
SRM	Safety Risk Management
SSCs	Structures, Systems, and Components
SSM	State Supervision of Mines
TOR	Tolerability of Risk
TR	Temporary Refuge
TRI	Temporary Refuge Integrity
U.S.	United States
UK	United Kingdom
USCG	United States Coast Guard
VPF	Value of Preventing a Fatality
WOAD	Worldwide Offshore Accident Databank
WOMP	Well Operations Management Plan

1. Introduction

> The *Bureau of Safety and Environmental Enforcement (BSEE) is focused on the reduction of offshore risk… Part of managing risk is monitoring the trends we are seeing offshore, and gauging the effectiveness of our approach. This not only provides a valuable perspective on risks, it helps direct our future efforts. Moreover, information of this nature needs to be shared among all stakeholders, so that we have a common appreciation for the progress that has been made as well as the challenges ahead.*
>
> Director Salerno
> Annual Report 2014

1.1. Project Objectives

BSEE is committed to proactively identifying, analyzing, communicating, and managing risks related to outer continental shelf (OCS) oil and gas exploration and production activities. For decades BSEE and its predecessor, the Mineral Management Service (MMS), have been dedicated to overseeing these activities to ensure safe and clean operations. Over these years, BSEE has developed a good understanding of the unique risks posed by OCS activities and the measures that can be employed to manage those risks to acceptable levels. While this knowledge provides a strong foundation, BSEE lacks an operational risk management program that enables systematic, transparent, auditable, and goal-focused management of risks. Toward that end, in September 2014, BSEE awarded the *Evaluation of the Collection and Application of Risk Data* contract to ABS Consulting to develop recommendations to help BSEE build an operational risk management program.

Project Objectives

1. Conduct a meta-study of how other international and United States (U.S.) regulators collect and use risk data
2. Recommend risk methodologies for application to key BSEE decision-making processes
3. Develop a concept for a BSEE operational risk management program
4. Provide a high-level implementation plan for the first few years of the program

1.2. Evaluation Process

ABS Consulting assembled a team of risk experts made up of members from key oil and gas producing nations, including the U.S., United Kingdom (UK), and Norway. This team had significant prior experience in working with many of the risk management programs evaluated during this effort. The evaluation team, with guidance from BSEE experts in the Office of Offshore Regulatory Programs (OORP), applied its experience to achieve the project objectives by executing the following steps:

1. Conducted initial research to identify risk management programs implemented by a variety of international and U.S. regulatory agencies
2. Prioritized other agency risk management programs for further research

3. Gathered details about other agency risk management programs and profiled inputs, models, outputs, and decisions
4. Developed a toolkit of risk methodologies that could be employed with BSEE based on best practices of other agency programs and described how they could be tailored to support a variety of applications within BSEE
5. Established a concept for an operational risk management program that evolves over time to generate quality risk information, promote alignment across initiatives, and make efficient use of analytical resources
6. Provided recommendations on how the risk management program could be developed over time

1.3. Agency Review

Table 1 provides a high-level overview of each agency that the evaluation team reviewed and provides a brief description of their mission and responsibilities.

Table 1. Agencies Reviewed

International Agencies[2]
Agencia Nacional do Petroleo (ANP) is responsible for the regulation of the activities that are related to oil, natural gas and biofuel industries in Brazil. Key missions include: • Regulation of oil and gas industry activities • Authorization of development activities • Promoting licenses and signing agreements for exploration, development, and production • Inspection of operations to ensure regulatory compliance
Canada-Newfoundland Offshore Petroleum Board (C-NLOPB) is responsible for the regulatory mandates from the Atlantic Accords Act which include: safety, environmental protection, resource management and industrial benefits. The Board regulates exploration licenses, significant discovery licenses, and production licenses covering an area of 7,365,000 hectares; that is an area of about two-thirds of the size of the island portion of the Province of Newfoundland and Labrador. In the implementation of its mandate, the role of the C-NLOPB is to facilitate the exploration for and development of the hydrocarbon resources in the Newfoundland and Labrador Offshore Area in a manner that conforms to the statutory provisions for: worker safety; environmental protection and safety; effective management of land tenure; maximum hydrocarbon recovery and value; and Canada/Newfoundland & Labrador benefits.
Canada-Nova Scotia Offshore Petroleum Board (C-NSOPB) is responsible for the regulation of offshore petroleum activities providing high benchmarks for others to emulate. Its mandate is to apply the provisions of federal and provincial Atlantic Accords Act legislation governing offshore oil and gas activities, including: health and safety of workers; protection of the environment; management and conservation of petroleum resources; Canada-Nova Scotia employment and industrial benefits; issuance of licenses for exploration and development; and resource evaluation, data collection, curation and distribution.

[2] See Appendix F for a more detailed summary of each international agency reviewed as part of this project.

Comision Nacional de Hidrocarburos (CNH) is responsible for the regulation and supervision of the exploration and extraction of hydrocarbons. CNH oversees Mexican Petroleum (PEMEX) to ensure that projects:

- Obtain the maximum oil and gas volumes from the reservoir
- Replace hydrocarbon reserves
- Use appropriate technology for exploration and production
- Protect the environment and sustain natural resources
- Conduct activities safety
- Minimize flaring and venting of gas during extraction

Danish Energy Agency (DEA) is responsible for the entire chain of tasks linked to energy production and supply, transportation and consumption, including energy efficiency and savings as well as Danish national CO2 targets and initiatives to limit emissions of greenhouse gasses. DEA supports building-policy initiatives to increase the productivity and quality of building as well as the operation and maintenance of buildings, with focus on sustainable building. It also collaborates with the building sector to establish a good framework for the industry.

In addition, DEA is the sole responsible authority for health and safety on offshore oil installations. Offshore installations are understood as systems for exploration and production of oil and gas from beneath the seabed. In regards to security, this includes the built-in safety systems and equipment as well as safety in the workplace and at work. In regards to health, this includes health conditions in the work environment and other health conditions, which also includes workers staying at the installations outside work hours.

Department of Labour is responsible for improving the performance of the labor market and, through this, strengthening the economy and increasing the standard of living for those in New Zealand. The Department of Labour was integrated into the new Ministry of Business, Innovation and Employment (MBIE) on July 1, 2012. As part of this re-organization, MBIE established WorkSafe NZ, New Zealand's workplace health and safety regulator.

WorkSafe NZ is responsible for health and safety in the areas of agriculture, construction, energy, forestry, and manufacturing. Additional focus areas include New Zealand's tourism and adventure activities industries, asbestos, the rebuilding of Canterbury, hazardous substances, and other "high hazards" including offshore operations. Responsibility for petroleum operations in New Zealand is spread across six different government agencies. WorkSafe is solely responsible for enforcing and reviewing industry Safety Cases.

The **European Commission** is the European Union's (EU's) executive body representing the interests of the EU as a whole - not the interests of individual countries. The Commission's main roles are to:

- Propose legislation which is then adopted by the co-legislators, the European Parliament and the Council of Ministers
- Enforce European law
- Set objectives and priorities for action
- Manage and implement EU policies and the budget
- Represent the Union outside Europe (e.g., negotiating trade agreements)

Health & Safety Executive (HSE) is responsible for ensuring that the Health and Safety at Work Act of 1974, which provides regulatory framework for work place health and safety in Great Britain, including the offshore oil industry, is enforced. HSE's mandate is to make sure that the 'duty' of Employers to manage levels of risk, such as the offshore oil industry, is properly executed and As Low As Reasonably Practicable (ALARP). HSE maintains a 'Risk Based' approach, meaning the U.K. penalizes employers (fines) for causing harm to employees or members of the public, because, by definition, they have failed to do their duty to protect them.

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) is responsible for independently and professionally regulating offshore safety, well integrity and environmental management in the regulating offshore areas in Australian waters, as well as designated coastal waters where functions have been conferred.

Petroleum Safety Authority (PSA) is responsible for safety, emergency preparedness and the working environment in the Norwegian petroleum industry. Specifically, activities in this discipline are directed at drilling and well equipment on fixed installations and mobile units, and at the actual wells on the continental shelf. They cover the operational life of a well from the start of project planning until it has been finally plugged and abandoned.

State Supervision of Mines (SSM) is responsible for overseeing the compliance with statutory regulations applicable to mineral exploration, extraction, storage and transport of minerals, focusing on the aspects of health, safety, the environment, effective extraction and soil movements. SSM is a governmental organization and is situated in The Hague, Netherlands. The department falls under the ministerial responsibility of the Minister of Economic Affairs, Agriculture and Innovation. SSM also works for the Ministers of Socials Affairs and Employment (for labor laws); Housing, Spatial Planning and the Environment (for environmental legislations); and Health, Welfare and Sport (for criminal investigation).

U.S. Agencies

Department of Energy (DOE) is responsible for ensuring America’s security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions. In addition, DOE catalyzes the timely, material, and efficient transformation of the nation’s energy system and secures U.S. leadership in clean energy technologies. As part of this mission, DOE safely and cost-effectively transports and disposes of low-level wastes; decommissions and decontaminates old facilities; remediates contaminated soil and groundwater; and secures and stores nuclear material in stable, secure locations to protect national security.

Department of Transportation (DOT) is responsible for ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future. DOT also develops and coordinates policies that will provide an efficient and economical national transportation system, with due regard for need, the environment, and the national defense. It is the primary agency in the federal government with the responsibility for shaping and administering policies and programs to protect and enhance the safety, adequacy, and efficiency of the transportation system and services.

Environmental Protection Agency (EPA) is responsible for protecting human health and the environment and ensuring that all Americans are protected from significant risks to human health and the environment where they live, learn and work; national efforts to reduce environmental risk are based on the best available scientific information; and that federal laws protecting human health and the environment are enforced fairly and effectively.

Federal Aviation Administration (FAA) is responsible for regulating and overseeing all aspects of American civil aviation. This includes regulating U.S. commercial space transportation as well as regulating air navigation facilities' geometry and flight inspection standards. The FAA also encourages and develops civil aeronautics, including new aviation technology; issues and suspends, or revokes pilot certificates; and, regulating civil aviation to promote safety, especially through local offices called Flight Standards District Offices.

Food and Drug Administration (FDA) is responsible for protecting the public health by ensuring the safety, efficacy and security of human and veterinary drugs, biological products, medical devices, our nation’s food supply, cosmetics, and products that emit radiation. The FDA is also responsible for advancing the public health by helping to speed innovations that make medicines more effective, safer, and more affordable and by helping the public get the accurate, science-based information they need to use medicines and foods to maintain and improve their health. FDA also has responsibility for regulating the manufacturing, marketing and distribution of tobacco products to protect the public health and to reduce tobacco use by minors. Finally, the FDA plays a significant role in the Nation’s counterterrorism capability. FDA fulfills this responsibility by ensuring the security of the food supply and by fostering development of medical products to respond to deliberate and naturally emerging public health threats.

Mine Safety & Health Administration (MSHA) is responsible for helping to prevent death, disease, and injury from mining and promotes safe and healthful workplaces for the Nation's miners. MSHA inspectors issue a citation or order for each violation of a health or safety standard they observe. Each issuance entails a civil penalty.

National Aeronautics and Space Administration (NASA) is responsible for the civilian space program as well as for aeronautics and aerospace research. NASA remains a leading force in scientific research and in stimulating public interest in aerospace exploration, as well as science and technology in general. In particular, in regards to aeronautics, NASA manages research focused on meeting global demand for air mobility in ways that are more environmentally friendly and sustainable, while also embracing revolutionary technology from outside aviation.

Nuclear Regulatory Commission (NRC) is responsible for ensuring the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment. The NRC regulates commercial nuclear power plants and other uses of nuclear materials, such as in nuclear medicine, through licensing, inspection and enforcement of its requirements. NRC's regulatory mission covers three main areas: 1) Reactors - Commercial reactors for generating electric power and research and test reactors used for research, testing, and training, 2) Materials - Uses of nuclear materials in medical, industrial, and academic settings and facilities that produce nuclear fuel, and 3) Waste - Transportation, storage, and disposal of nuclear materials and waste, and decommissioning of nuclear facilities from service.

Occupational Safety and Health Administration (OSHA) is responsible for ensuring safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance. OSHA establishes common sense standards and enforces the law against those who put workers at risk. OSHA standards protect workers from toxic chemicals and deadly safety hazards at work, ensuring that vulnerable workers in high-risk jobs have access to critical information and education about job hazards, and providing employers with vigorous compliance assistance to promote best practices that can save lives.

United States Coast Guard (USCG) is responsible for maritime safety, security, and stewardship. The USCG protects the personal safety and security of our U.S. citizens; the marine transportation system and infrastructure; U.S. natural and economic resources; and the territorial integrity of our nation–from both internal and external threats, natural and man-made. The USCG also protects these interests in U.S. ports and inland waterways, along the coasts, on international waters. The USCG is a military, multi-mission, maritime force offering a unique blend of military, law enforcement, humanitarian, regulatory, and diplomatic capabilities.

1.4. Formal Risk Management Programs

Most of the agencies described in Table 1 have a responsibility for reducing risk to the public, workers, or the environment within the industries they regulate; however, only a subset of them has developed formal risk management programs or capabilities. The evaluation team performed a high-level review of each agency, identified their formal risk management programs, and prioritized each program for further research based on its applicability to BSEE.

Table 2 provides the results of the evaluation team's assessment. A number of agencies did not have a formal risk program; therefore, they were not included in the prioritization. Also note that several agencies maintain "Safety Case" regimes, modeled after the UK's approach. The evaluation team selected only the UK's program for high review priority even though many of the regimes are very similar.

Table 2. Agency Risk Management Programs

Agency	Risk Management Program	Review Priority
	International Agency Programs	
Petroleum Safety Authority Norway	**Trends in Risk Level in the Petroleum Activity (RNNP).** Annual process that measures and improves safety/environmental conditions	High
HSE	**Safety Case.** Industry-prepared product identifying risks and illustrating risk reduction to ALARP required for design approval or operating permit	High
Danish Energy Agency	**Health & Safety Case.** Industry-prepared product identifying risks and illustrating risk reduction to ALARP required for design approval or operating permit	Medium
Department of Labour	**Safety Case.** Industry-prepared product identifying risks and illustrating risk reduction to ALARP required for design approval or operating permit	Medium
European Commission	**SEVESO II.** Industry-prepared product for complex, land-based industrial sites requiring a risk assessment characterizing (1) individual risk for workers and the environment, (2) societal risk for surrounding populations, and (3) risk reduction from mitigation measures for ALARP demonstration.	Medium
NOPSEMA	**Safety Case.** Industry-prepared product identifying risks and illustrating risk reduction to ALARP required for design approval or operating permit	Medium
State Supervision of Mines Ministry of Economic Affairs	**Safety Case.** Industry-prepared product identifying risks and illustrating risk reduction to ALARP required for design approval or operating permit	Medium
Canada-Newfoundland Offshore Petroleum Board	**Strategic Environmental Assessments.** Examines potential environmental effects associated with a plan	Low
CNSOPB		Low
anp Agência Nacional do Petróleo	No relevant formal risk management program	
	U.S. Agency Programs	
U.S.NRC	**Risk-Informed Regulations and Inspections Program.** Complex, integrated NRC and industry risk analysis and management system to inform regulations and inspections	High
NASA	**Accident Precursor Analysis (APA).** Screens and evaluates anomaly impacts on risk profile	High
	National Maritime Strategic Risk Assessment (NMSRA). Biennial strategic risk assessment across all USCG missions	High
	Risk-Based Inspections. New pilot project to develop a risk-based vessel inspection protocol	High
U.S. Department of Labor MSHA Mine Safety & Health Administration	**Risk & Readiness Models.** Pilot program for voluntary industry-performed risk and readiness assessments	High
FDA	**Risk-Based Inspections.** Prioritizes frequency of inspections for food establishments and pharmaceutical sites based on risk factors	Medium
Federal Aviation Administration	**Safety Risk Management (SRM)**. Provides a systematic and integrated method for managing safety of air traffic control and navigation services in the National Airspace System. Major elements include: (1) policy, (2) architecture, (3) assurance, and (4) safety promotion	Medium
U.S. Department of Labor MSHA Mine Safety & Health Administration	**Quantitative Risk Assessment in Support of Rulemaking.** Quantifies health effect risk to miners from occupational exposures	Low
Department of Energy United States of America	**Documented Safety Analysis (DSA).** Safety basis regulation for DOE non-reactor nuclear facilities [10 CFR 830]	Low

Agency	Risk Management Program	Review Priority
	Risk Management Plan (RMP). Regulation requiring facilities that use extremely hazardous substances to develop a risk management plan.	Low
	No relevant formal risk management program	
OSHA	No relevant formal risk management program	

2. Risk Analysis and Management Fundamentals

Risk management is the process to identify and manage the estimated impact of uncertain events toward acceptable levels. The recommended risk management cycle is made up of five phases as shown in Figure 1: (1) setting strategic goals, objectives, and determining constraints; (2) assessing the risks; (3) evaluating alternatives for addressing these risks; (4) selecting the appropriate alternatives; and (5) implementing the alternatives and monitoring the progress made and the results achieved. This cycle was introduced by the Government Accountability Office (GAO)[3] in 2005. The GAO risk management cycle, while generic, provides a useful framework for weighing the value of alternate risk mitigation strategies. This process organizes information about the possibility of a spectrum of unwanted outcomes into an inclusive, orderly structure that helps decision makers make more informed choices about their organization's ability to reduce risks.

Figure 1. GAO Risk Management Cycle

The following sections outline a high-level approach for developing a risk management program addressing all phases of the risk management cycle.

2.1. Phase 1 – Strategic Goals, Objectives, and Constraints

This phase involves establishing the scope and structure of the risk-informed decision-making process. Critical steps in this phase include:

Understand and define the decision. Specifically describe what decision(s) must be made and what options are available to the decision maker.

[3] Government Accountability Office; PROTECTION OF CHEMICAL AND WATER INFRASTRUCTURE Federal Requirements, Actions of Selected Facilities, and Remaining Challenges, March 2005, GAO-05-327

Determine who should be involved. Input from key stakeholders is essential to a sound risk management process. Planners at all levels should identify and solicit input from stakeholders who should be involved in making the decision, and those who will be affected by actions resulting from the decision-making process. In a regulatory context, the regulated industry is certainly a key stakeholder. The level of involvement from industry depends on how heavily the risk management process relies on industry participation and cooperation. A government-driven process may require little input from industry when compared to an industry-driven approach.

Identify the factors that will influence the decisions. The decision to pursue a given strategy is not based solely on risk. For each individual element within a strategy and for the strategy as a whole, decision makers must weigh a number of factors, including:

- Will the strategy be effective in reducing risk?
- Is it feasible to implement?
- Is it cost efficient?
- How will risk reduction be measured?

Establish formal risk acceptance/tolerance criteria. The risk-informed decision-making process relies on an assessment of whether or not the identified risks are tolerably low. Examples of risk acceptance/tolerance criteria are ALARP, continuous improvement, and frequency thresholds.

Establish Common Risk Terminology. A common lexicon for risk discussion reduces poor communication that might lead to gaps and redundancies in application of risk-informed processes.

2.2. Phase 2 – Risk Assessment

Risk information fundamentally seeks to help decision-makers answer the three questions introduced in Figure 2.

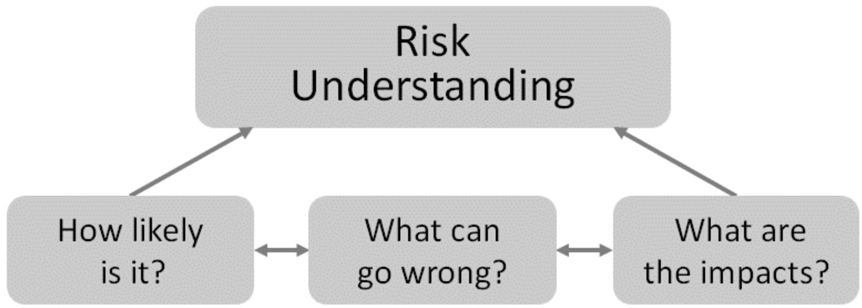


Figure 2. Fundamentals of Risk Understanding

1. What can go wrong? This is typically captured as a mutually exclusive but collectively exhaustive set of scenarios.
2. How likely is it? This is typically captured in the threat and vulnerability analyses.
3. What are the impacts? This can be impacts to people, property damage, business interruption, and environmental impacts, among others.

Risk identification and assessment can cover a wide range of approaches from simple screening methods to quite sophisticated quantitative modeling approaches. The key is to always fit the level of sophistication employed to the level of information needed by decision makers; this information is typically derived from a combination of the following sources:

- Historical experience
- Analytical methods
- Subject matter expert (SME) judgment

The following steps must be performed to assess risk:

Establish the risk-related questions that need answers.
Decide what questions, if answered, would provide the risk insights needed by the decision maker.

Determine the risk-related information needed to answer the questions.
Describe the information necessary to answer each question posed in the previous step. For each information item, identify the following:

- Information type needed
- Precision required
- Certainty required

Select the risk analysis method and tool.
Risk modeling techniques vary by the cost of use, the level of precision and certainty of output produced (information), and the required quality of input data. Section 2.7 explores these issues in greater detail. Table 3 lists a number of commonly used methods where the "Level of Effort" column indicates a general categorization of the amount of analytical resources required to implement the method.

Table 3. Risk Assessment Methods[4]

Risk Assessment Methods	Description	Level of Effort
Trend Analysis	Trend analysis is a technique to analyze historical accident and near miss data over time to identify consistent trends to predict future accidents. This technique is best suited to high frequency/low severity profiles.	Low
Pareto Analysis	Pareto analysis is a ranking technique based only on past data that identifies the most important items among many. This technique uses the 80-20 rule, which states that about 80 percent of the problems are produced by about 20 percent of the causes.	Low
Relative Ranking/Risk Indexing	Relative ranking/risk indexing uses measurable features of an operation or facility to calculate index numbers that are useful for comparing risks of different options. These index numbers can, in some cases, be related to actual performance estimates.	Low to Medium

[4] Appendix A provides a detailed exploration of select risk assessment methods

Risk Assessment Methods	Description	Level of Effort
Pairwise Comparison	Pairwise comparison is a risk ranking technique for multiple issues that relies on a collection of SMEs systematically rating the relative risks between combinations of two issues. This relative ranking is repeated for every possible combination, and the group results are combined mathematically to generate summary rankings.	**Low to Medium**
Preliminary Risk Analysis (PrRA)	PrRA is a simplified approach to accident-based risk assessment. The main goal of the technique is to define the risk related to important accident scenarios. This team-based approach relies on SMEs examining the issues. The team suggests possible accidents, most important contributors to accidents, and protective features. The analysis also identifies the risk of the accidents and identifies recommendations for reducing risk.	**Low to Medium**
What-if Analysis	What-if analysis is a problem-solving approach that uses loosely structured questioning to (1) suggest upsets that may result in accidents or system performance problems and (2) make sure the proper safeguards against those problems are in place.	**Low to Medium**
Layer of Protection Analysis (LOPA)	LOPA is a technique to systematically identify and assess the number and strength of layers of protection against major accident hazards. This information is used to make consistent and rational decisions on the adequacy of existing or proposed layers of protection.	**Medium to High**
Bowtie Analysis	Similar to LOPA, bowtie analysis is a technique for identifying layers of protection for major accident hazards, but bowtie enables analysts to consider multiple scenarios simultaneously. Bowtie is a particularly effective technique for communicating the relationships between prevention/mitigation layers and the scenarios they address.	**Medium to High**
Failure Modes and Effects Analysis (FMEA)	FMEA is a reasoning approach best suited to reviews of mechanical and electrical hardware systems. The FMEA technique (1) considers how the failure modes of each system component can result in system performance problems and (2) makes sure the proper safeguards are in place. A quantitative version of FMEA is known as failure modes, effects, and criticality analysis (FMECA).	**Medium to High**
Hazard and Operability (HAZOP) Analysis	The HAZOP analysis technique uses special guide words for (1) suggesting departures from design intents for sections of systems and (2) making sure that the proper safeguards are in place to help prevent system performance problems.	**Medium to High**
Event Tree Analysis (ETA)	ETA is an analysis technique that uses decision trees to model the possible outcomes of an event that can produce an accident of interest. Probabilities and frequencies can be added to the analysis to estimate risks numerically.	**High**
Fault Tree Analysis (FTA)	FTA is a technique that graphically models how logical relationships between equipment failures, human errors, and external events can combine to cause specific accidents of interest. Probabilities and frequencies can be added to the analysis to estimate risks numerically.	**High**
Change Analysis	Change analysis looks logically for possible risk effects and proper risk management strategies in changing situations (e.g., when system layouts are changed, when operating practices or policies change, when new or different activities will be performed).	**Low to High**

Establish the scope for the analysis method(s) and tool(s).

Set any appropriate physical or analytical boundaries for the analysis.

Generate risk-based information using the analysis method(s) and tool(s).
Apply the selected risk analysis tool(s). This may require the use of more than one analysis tool and may involve some iterative analysis (i.e., starting with a general, low-detail analysis and progressing toward a more specific, high-detail analysis).

2.3. Phase 3 – Alternatives Evaluation

The goal of most decision-making processes is to lower risk as much as possible. Sometimes the risk will be acceptable; at other times, the risk must be reduced to become acceptable. To reduce risk, action must be taken to manage it. These actions should provide more benefit than they cost. They must also be acceptable to stakeholders and not cause other significant risks. Key steps in this process are:

Develop alternate strategies to manage risk.
The analysis team should engage the appropriate stakeholders to determine how the risks for each scenario can be managed most effectively. Each alternative should be completely developed by documenting a number of critical factors, including how the elements of the alternative will interact with the scenario to reduce risk, estimated costs, schedules, and implementation risks.

Assess the risk impact of the proposed alternatives.
The planning team should reassess the risk of each scenario assuming the implementation of each alternative based on the expected effectiveness of the alternatives. This step will characterize risk reduction for each of the alternate strategies. Again, the sophistication of the risk impact assessment should be guided by the information required by decision makers. While quantitative estimates of risk reduction might be optimal, qualitative assessment of the alternative might be sufficient to inform the planning process.

2.4. Phase 4 – Management Selection

Once the alternatives have been fully developed and their risk reduction value has been described either qualitatively or quantitatively, the risk management process moves to the management selection phase where decision makers choose the collection of alternatives for implementation.

A risk-informed approach to planning involves more than using risk assessments and analysis to drive prioritization of plans and evaluate between separate alternatives. The plan development process also has to take into account the many factors related to implementation of the alternative, such as external dependencies, resource availability, and change management. In doing so, all levels of plans need to identify potential issues that could arise and threaten successful execution, as well as ways to address them.

In this case, risk is more than just operational risk. It also includes risk of a failed execution of a portion of the plan (or the entire plan), as well as organizational risk associated with the plan. By necessity, all plans acknowledge or imply a certain level of residual risk that needs to be managed. It is up to the senior leader as part of the approval process to determine if a plan takes on too much risk or if the risk is not appropriately managed. Planning assumptions generally help define risk management considerations, which need to be taken into account. As plans are created, however, these assumptions need to be tested and evaluated to ensure that they do not exceed an appropriate level of risk.

2.5. Phase 5 – Implementation & Monitoring

The process then moves into implementation of chosen alternatives and the ongoing monitoring to ensure they are functioning as intended. Critical steps in this phase include:

Implement the chosen mitigation strategies.
This step involves the implementation of the alternatives identified during the management selection phase. These will often take the form of a project and require deliberate planning and management of implementation tasks.

Develop metrics to measure effectiveness.
The implementation team should develop a collection of metrics, both qualitative and quantitative, to measure the effectiveness of the alternative. These may include outcome-oriented metrics, leading indicators, or lagging indicators.

Monitor organizational performance.
After the strategies have been implemented and the metrics have been developed, the organization should monitor the effectiveness of the actions taken to manage risk. The goal of the monitoring phase is to verify that the organization is getting the expected results from its risk management decisions. Key inputs into the monitoring phase include testing, training, and exercising. The results of the monitoring step will inform subsequent iterations of the risk management cycle.

2.6. Risk Communication

Throughout the process of developing and implementing a risk management process, stakeholders should communicate freely for two reasons. First, stakeholders who are included in the development of the risk management system can contribute their own expertise and feedback to the process, improving the precision and certainty of the systems' results and eventual decisions. Second, the inclusion of many stakeholders in the process generates consensus around points of disagreement before the results are ever applied in the decision-making process, which increases stakeholder buy-in.

2.7. Risk Information and Modeling

Table 3 introduces a variety of risk modeling techniques with varying levels of complexity that generate outputs with various levels of precision and certainty. This section further explores the trade-offs between risk information quality and the resources required to generate information.

Risk models rely on inputs to help generate information about the possibilities for unwanted outcomes to help decision makers make more informed choices. Input data can be of varying degrees of quality, which can be described in three facets:

- **Data accuracy** is the degree to which the data reflect reality. Data inaccuracy might result from errors in data collection, missing data, or random variation in observed values.
- **Data precision** is the level of detail expressed in the data. For numerical data, precision might mean the number of digits shown after the decimal point. For non-numerical data, an example of varying precision is whether a location is expressed as (1) detailed latitude/longitude degrees-minutes-seconds pairings, (2) a street address, or (3) high-level city or state information.

- **Data relevance** describes how closely data fit the purpose for which they are used. Sometimes data are adapted for a use other than their original purpose or are collected prior to the identification of a specific use. If data are only approximately relevant, they might be accurate and appropriately precise but not sufficient to yield high-accuracy results when used in a model. This might be the case when available data are used as a proxy for more relevant data that are not available.

Theoretically, it may be possible to collect data that are as accurate, precise, and relevant as desired, but practically, any data or collection process is limited by analytical constraints. In the field of big data[5] analytics, these fundamental constraints are often expressed as the "three Vs":

- **Volume** is the problem of having a large number of records and/or fields in a dataset. The higher the data volume, the harder it can be to comprehend features of the data and the longer it may take for computers to process the data.
- **Variety** is the problem of data being inconsistently formatted or unstructured. For example, requiring operators to provide spreadsheet summaries of their operations may yield a lot of informative data. However, if each organization arranges its summary in a different format, it may be difficult to make these data useful. This is variety due to inconsistent formatting. Unstructured data, such as free text data, also present variety issues.
- **Velocity** of data occurs when new data are continually becoming available and, therefore must be processed continually to be relevant.

Although continued increases in computing power have made big data[5] analytics less of a challenge than in the past, the three Vs must still be considered when developing data collection programs; however, the pursuit of improved data relevance, data accuracy, and data precision often necessitates increasing the analytical load in terms of the volume, variety, and velocity of the data collected.

This pursuit must take a balanced approach where the benefits of data quality improvement outweigh the increased analytical load. Examples include:

- Increased data volume improves data accuracy and statistical confidence
- Collecting a higher volume and variety of data increases the probability of collecting data relevant to future, unknown analyses
- High-velocity data enable real-time decision-making support

Increasing the analytical load does not always lead to improved data quality. For instance, poorly standardized data collection (high variety) might create inconsistent levels of precision or accuracy in a dataset. If the inconsistency leads analysts to accept the lowest level of precision or accuracy, then quality has been lost despite the increase in analytical load.

The purpose of collecting data is to support decision making. It is the foundation of the process, but data alone may not be inherently useful. Rather, making data useful is often a progression from data to information to knowledge and finally to insight (Figure 3).

[5] http://www.gartner.com/it-glossary/big-data

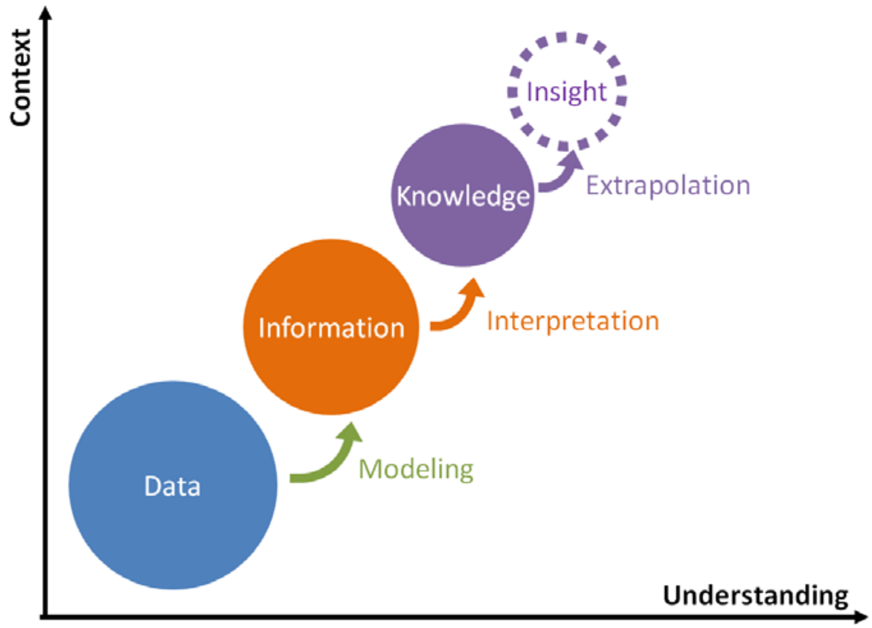


Figure 3. Development of Data into Insight[6]

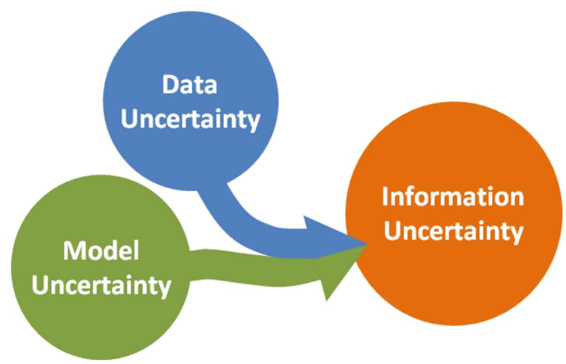


Figure 4. Sources of Information Uncertainty

A well-designed risk management process can convert data into information. Like data, information also has dimensions of quality. The concepts of data relevance and precision can be applied just as easily to information. However, instead of accuracy of individual data elements, certainty becomes a key facet of information quality. The distinction between accuracy and certainty, while subtle, is essential to understand in the development of a risk management process.

Information uncertainty is a function of both data uncertainty (the perception of data accuracy) and model uncertainty (Figure 4). In general, a model's output information will not be of higher quality than its input data. Likewise, a model's analytical scope and complexity will determine how well the model reflects reality or predicts future outcomes. Applying very high quality data within a model that does not appropriately address key factors may yield highly uncertain results. Whether there are major quality issues with the data or major logic issues within the model, the old adage holds true: garbage in, garbage out.

[6] http://www.systems-thinking.org/dikw/dikw.htm

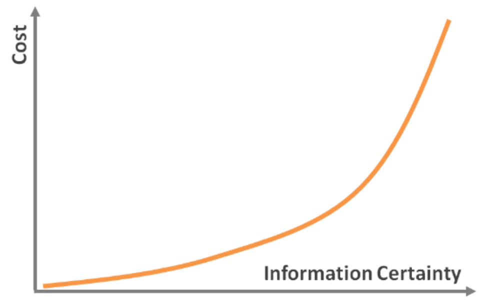


Figure 5. Information Certainty and Cost Trade-off

In any decision-making process, there is a constant struggle between the need for higher quality information and the analytical load to generate the improved information (Figure 5). Even when a lot of data are collected and risk information is generated, a great deal of uncertainty may remain. So, decision makers and risk analysts must work together to make sure the cost of collecting more accurate data or the cost of making modeling enhancements does not outweigh the benefits. This is why analysts should never use complex risk methodologies without first trying to meet information requirements with simpler tools.

Figure 6 presents that in order to gain better understanding of risks due to accidents, including future accident types that have not yet been observed or recognized, more information certainty and precision are required. To achieve higher levels of information certainty and precision, more resources will be required to improve model quality and execute the increased analytical load of gathering and maintaining higher quality data.

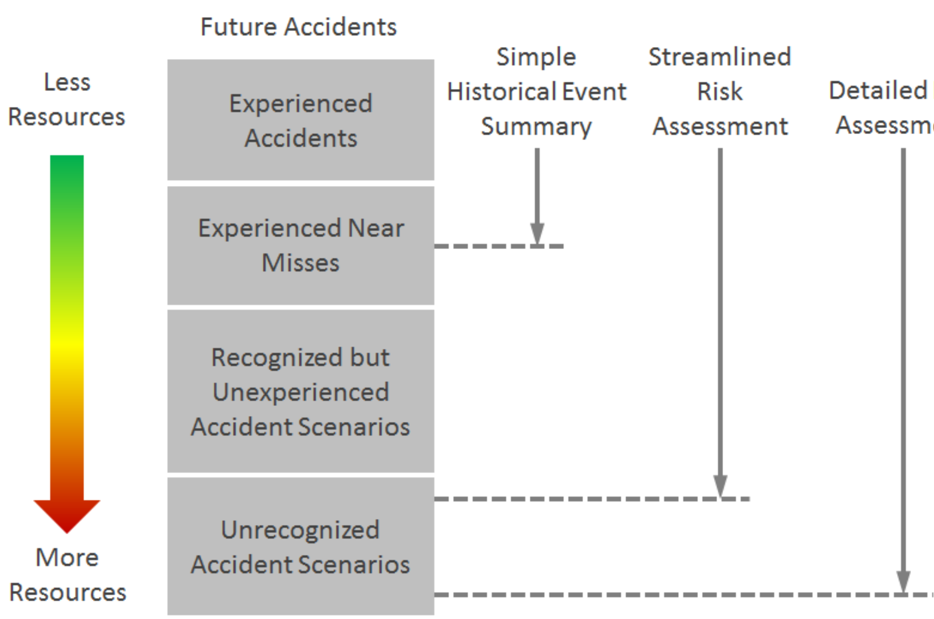


Figure 6. Dealing with Information Precision, Uncertainty, and Resource Needs

The progression of data to insight is along a continuum rather than discrete steps. Highly sophisticated model outputs might sometimes approach the threshold of knowledge. However, knowledge and insight generally arise from the human interpretation of information and the assimilation of that interpretation into the array of knowledge that humans use to anticipate the future issues and make decisions.

As risk management processes are conducted and information is generated, analysts should consider employing data visualization techniques to support the development of decision makers' knowledge and insight. Effective visualizations can be powerful tools to make complex information more accessible and easier to understand. Data visualization tools and techniques have evolved rapidly over the last several years providing the capability for analysts to visualize multiple dimensions of an issue simultaneously to efficiently identify trends and correlations with the information. Examples of data visualization (Figure 7) techniques, include: charts, graphs, network diagrams, heat maps, and infographics, and tools can be used to generate static outputs or can provide interactive exploration of the dataset by analysts.

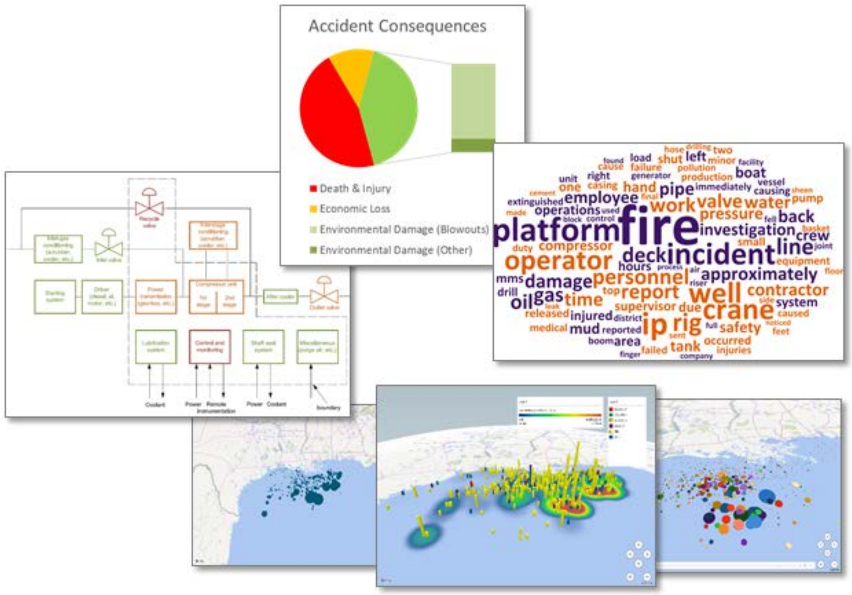


Figure 7. Example Data Visualizations

3. Key Risk Management Program Overviews

This section provides an in-depth exploration of each of the other government agency (OGA) risk management programs that were identified as high review priority in Table 2[7]. Each subsection describes key elements of the risk management program, including the program's input, models, outputs, and the decisions supported by the program.

For each program, the evaluation team provides:

- A synopsis of how the program fits into its sponsor agency's mission space
- A program overview diagram highlighting key inputs, models, outputs, and decisions
- Detailed table of information about each item depicted in the program overview diagram
- Trade-offs between information quality and analytical load
- Conclusions on key features of the program

Figure 8 is a legend to understand the program overview diagrams that are presented for each of the risk management programs by introducing the overall structure and key formatting items. Note that the darker-colored items represent inputs, models, outputs, or decisions related to the sponsoring government agency, while the lighter-colored items are related to industry or, in some cases, OGAs. The symbols shown in the sample graphic are not specific to a stakeholder type.

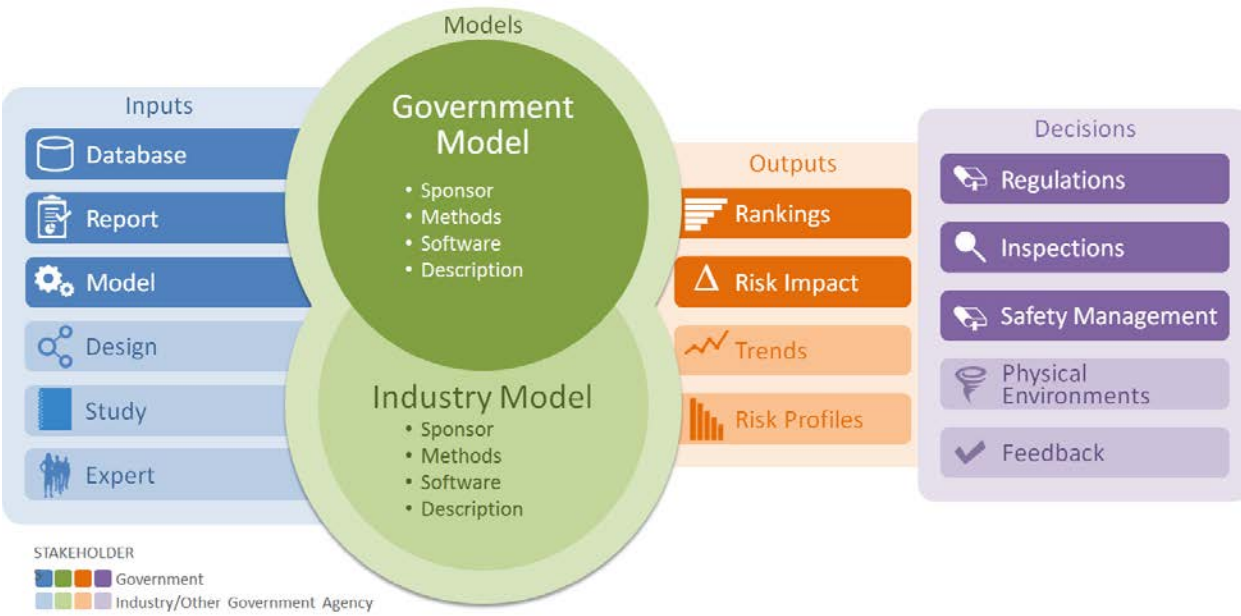


Figure 8. Program Overview Diagram Legend

[7] Note: the USCG's RBI and MSHA's Risk and Readiness Assessment programs have not been fully implemented and are not discussed in this section. See Appendix E for details on those programs.

Additional information is provided following each diagram. A detailed table explores each element of the diagram and fills in specific relevant information. Next, keying off of the framework of data and information discussed in Section 2.7, a balance diagram similar to Figure 9 will be color-coded to provide a concise summary of the key drivers of the output information quality to the government agency and the analytical load on the agency for collecting, storing, and processing both the inputs to and the outputs of the model. This diagram also addresses analytical load due to the model complexity. For example, if building and maintaining a high-complexity model require significant use of facility designs and plans as inputs, this fact will be reflected as high analytical load driven by high volume and variety of design and plan data. The color-coding represents the desirability of the element from the perspective of the agency where green is positive, red is negative, and yellow is in between.

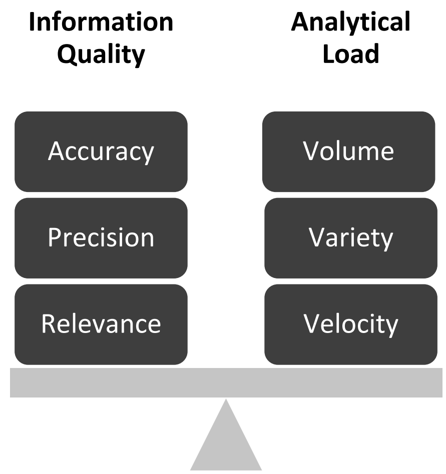


Figure 9. Information Quality vs. Analytical Load

3.1. HSE Safety Case

The HSE enforces worker safety regulations in the UK. It traces its history to the U.K.'s *Health and Safety at Work Act of 1974 (HS&W Act)*[8], which formally established a responsibility for employers to manage risk by stating:

> *It shall be the duty of every employer to ensure, So Far As Is Reasonably Practical (SFAIRP), the health, safety and welfare at work of all [his/her] employees.*

This performance-based philosophy has become the cornerstone of British safety regulation and has spread to several other European and Commonwealth countries. Following the Piper Alpha disaster in 1988, HSE gained jurisdiction over offshore oil and gas safety in the UK.

Most of the UK's offshore oil and gas is located in the deep water of the North Sea. Development of this region requires major capital outlay, and therefore, is largely dominated by large oil companies. Many of the first platforms installed in the 1970s are still operating today as companies seek to extend the life of their capital investment rather than construct new platforms. Although this reality may lead to an increased likelihood of accidents, HSE must help manage the potentially conflicting objectives of energy independence and safety. Until renewable energy technologies can make up the gap between energy production and consumption, extending the use of existing platforms offshore and drilling the remaining offshore oil reservoirs appear to be the only solution.

These pressures have not yet had a major effect on HSE's offshore safety objectives. However, some fear that the safety standards are weakening. In 2005, HSE relaxed periodic safety review requirements from every three years to every five years.[9] Simultaneously, HSE has had trouble maintaining the

[8] http://www.hse.gov.uk/aboutus/timeline/index.htm
http://www.legislation.gov.uk/ukpga/1974/37/contents
[9] Lessons from the North Sea: Should "Safety Cases" Come to America?

technical staff needed for performing the inspections that ensure the protocols identified in each Safety Case are being upheld. For additional details regarding the HSE's operations and regulatory context, see Appendix F.7.

3.1.1. ALARP Framework

To understand HSE's regulatory approach through its Safety Case program, it is essential to understand the background on the history and application of the ALARP standard. The ALARP, or SFAIRP, philosophy began to form in 1967 when F.R. Farmer developed an acceptable risk threshold for radioactive material releases. This concept was expanded to other operations when UK's Health and Safety Commission formed the Advisory Committee on Major Hazards following a vapor cloud explosion in Flixborough, UK. The committee determined that such major accidents were only tolerable if they occurred fewer than once per 10,000 years. The standard applied to a wide variety of major accidents, though the definition of a "major accident" was left to the employer (called dutyholder) to decide. Historically, any accident capable of producing ten fatalities was covered. Today, as few as three or even one fatality is considered major.

In 1983, the Royal Society Study Group developed the concepts of "as far as reasonably practicable" and an upper bound to acceptable risk. The HSE quickly assimilated the ideas into their Tolerability of Risk (TOR) framework. In the report "The Tolerability of Risk from Nuclear Power Stations," the HSE defined three tests that make up the TOR framework:

1. Is the given risk so great or the outcome so unacceptable that it must be refused altogether?
2. Is the risk so small, or has it been made so small, that no further precaution is necessary?
3. If the risk falls between these two extremes, has it been reduced to the lowest level that is reasonably practicable?

In 1989, the HSE published *Quantified Risk Assessment: Its Input to Decision Making* as a synopsis of quantitative risk assessment (QRA) practice and its use with risk tolerance standards. In 1992, the HSE revised its TOR report, maintaining its former risk tolerance thresholds and the application of ALARP when faced with risks that are neither unacceptable nor broadly acceptable.

In 2001, U.K. HSE rolled out a new decision-making process in a document called *Reducing Risks, Protecting People* (R2P2). This document explicitly addressed tolerable vs. intolerable risks by describing society's tolerance of risk with fatal consequences. The HSE determined that both the individual and societal risks presented by an operation must be addressed, and suitable controls must be in place to address all of the significant hazards. Operators have a duty to look after the health and safety of all workers as well as members of the public who may be affected by their operations.

Figure 10 illustrates a simplified TOR model that HSE presented in R2P2. The model presents a three-tiered schema that classifies risk into the following regions:

- **Unacceptable Region (top)** - Any activity within this region would not be allowed unless risk can be reduced to the lower regions.
- **Tolerable Region (middle)** – The risk associated with activities within this region is deemed to be tolerable, but where further, risk reduction measures should be considered for implementation.
- **Broadly Acceptable Region (bottom)** – The risk associated with activities within this region is considered adequately controlled, and further risk reduction is not required.

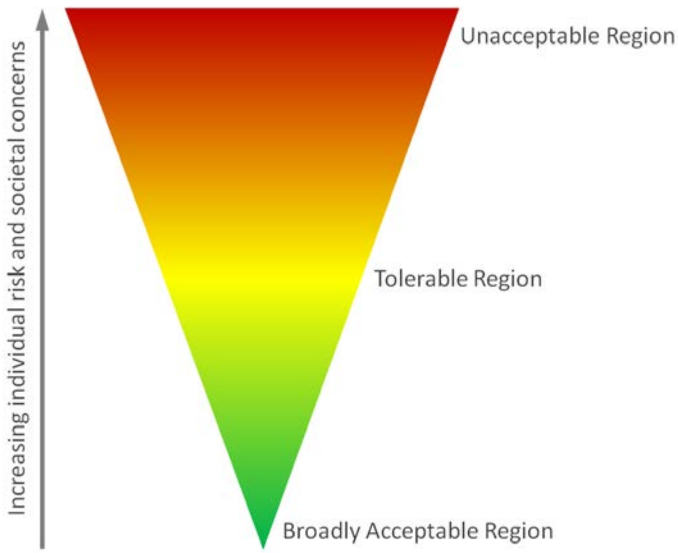


Figure 10. Tolerability of Risk Framework

This model suggests the creation of two risk criteria – an upper risk criterion defining the maximum tolerable risk, and a lower risk criterion defining broadly acceptable risk. Many companies and regulatory authorities have based their risk criteria on this model. Appendix 0 provides examples of how ALARP has been applied by other government agencies.

Others use a modified 2-region/single risk criterion model that does not contain the lower, broadly acceptable risk criterion. This modified model distinguishes between risks that are unacceptable and risks requiring further, prudent reduction. The 2-region model, in effect, implies a continuous improvement approach under which the company should remain alert to new opportunities to reduce risk, no matter how low the risk is currently. Key to the implementation of either of these models is the matter of what constitutes prudent efforts. The UK has addressed this need with the concept of reducing risk to ALARP. British courts have determined that the term *reasonably practicable* is a narrower term than *physically possible*.

As the ALARP concept has been developed over time, HSE has utilized the concept of “grossly disproportionate” to describe a cost/benefit interpretation of *reasonably practicable.* HSE has provided extensive guidance on the ALARP concept and the meaning of “grossly disproportionate”:

- By ‘grossly disproportionate,’ the HSE clearly intends that the ‘sacrifice’ (cost) that must be made to reduce the risk significantly be greater than the risk reduction achieved. Simple parity is not enough.
- The degree of disproportion is not intended to be constant over the entire risk spectrum. The HSE defines the ‘disproportion factor’ as the ratio of sacrifice required to risk reduction achieved. Under the ALARP concept, this disproportion factor would necessarily be greater as the risk approached the upper, intolerable risk level, and could be less for lower risks.
- The disproportion is intended, in part, to provide conservatism to compensate for any imprecision in the estimates of cost and benefit.
- Application of the ALARP principle does not relieve an organization of the responsibility for complying with recognized and generally accepted industry practices for risk controls.

The ALARP regulatory approach enables HSE to avoid the development of precise standards relating to technology that is continually changing. It is up to each operator to define their own risk thresholds. However, justification is required if these differ from the HSE’s guidance. HSE guidance established the following bounds for differentiating between these risks:

- If a worker is exposed to a risk of death greater than 1 in a 1,000 per year (1×10^{-3} annual exposure), it is intolerable.
- If a member of the public is exposed to risk of death greater than 1 in 10,000 per year (1×10^{-4} annual exposure), it is intolerable.
- If a worker or individual in the public is exposed to risk of death less than 1 in a million per year (1×10^{-6} annual exposure), the risk is broadly acceptable.

Most companies in the UK define their tolerability thresholds at 1 in 10,000 per year (1×10^{-6} annual exposure) for both workers and members of the public.

Figure 11 summarizes these standards visually in a TOR diagram. The values shown are the individual risk values (fatalities per year) that are typically used in the UK. In the region between the thresholds, industry must demonstrate that each employee’s risk of fatality is ALARP.

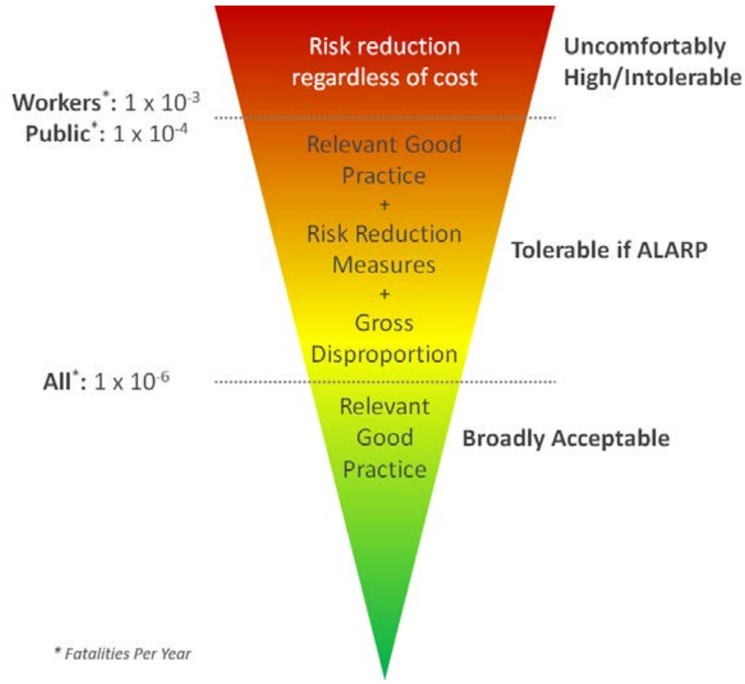


Figure 11. HSE Framework for Risk Tolerability

Dutyholder Compliance

U.K. offshore oil and gas platforms operate under a permissioning regime, where HSE's Hazardous Installations Directorate (HID), Energy Division (ED) allows dutyholders to operate if they follow regulations and prepare a Safety Case that demonstrates that the risk of their operation is:

1. **Tolerable**: falls below the intolerable threshold within the tolerable or broadly acceptable range
2. **ALARP**: costs of adding control measures would be grossly disproportionate to the benefits

The goals of this approach are to ensure operations are within societal risk tolerances and there is a rational balance between the costs of risk reduction and the value achieved in reducing the risk. If the costs are grossly disproportionate (e.g., cost/benefit ratio, which is also known as the Proportionality Factor [PF] > 10), then the further improvement is not required and the risk has been reduced to ALARP (assuming that the risk is lower than the tolerability threshold). If the costs are justified (e.g., PF < 10), then the assumption is that the improvements will be implemented. Even in this case, dutyholders must demonstrate that the costs for implementing the next barrier are grossly disproportionate.

Dutyholders must apply ALARP principles in the design of their operations considering the following:

- Controls used to manage the risk must achieve the standards of relevant good practice precautions, irrespective of specific risk estimates
- Where there is no relevant good practice, the decision as to what control measures are suitable will generally be informed by further risk assessment
- As control measures are introduced, the residual risks may fall so low that additional measures to reduce them further are likely to be grossly disproportionate to the risk reduction achieved (defined via Cost Benefit Analysis)

Figure 12 presents a notional process that a dutyholder would conduct to demonstrate ALARP.

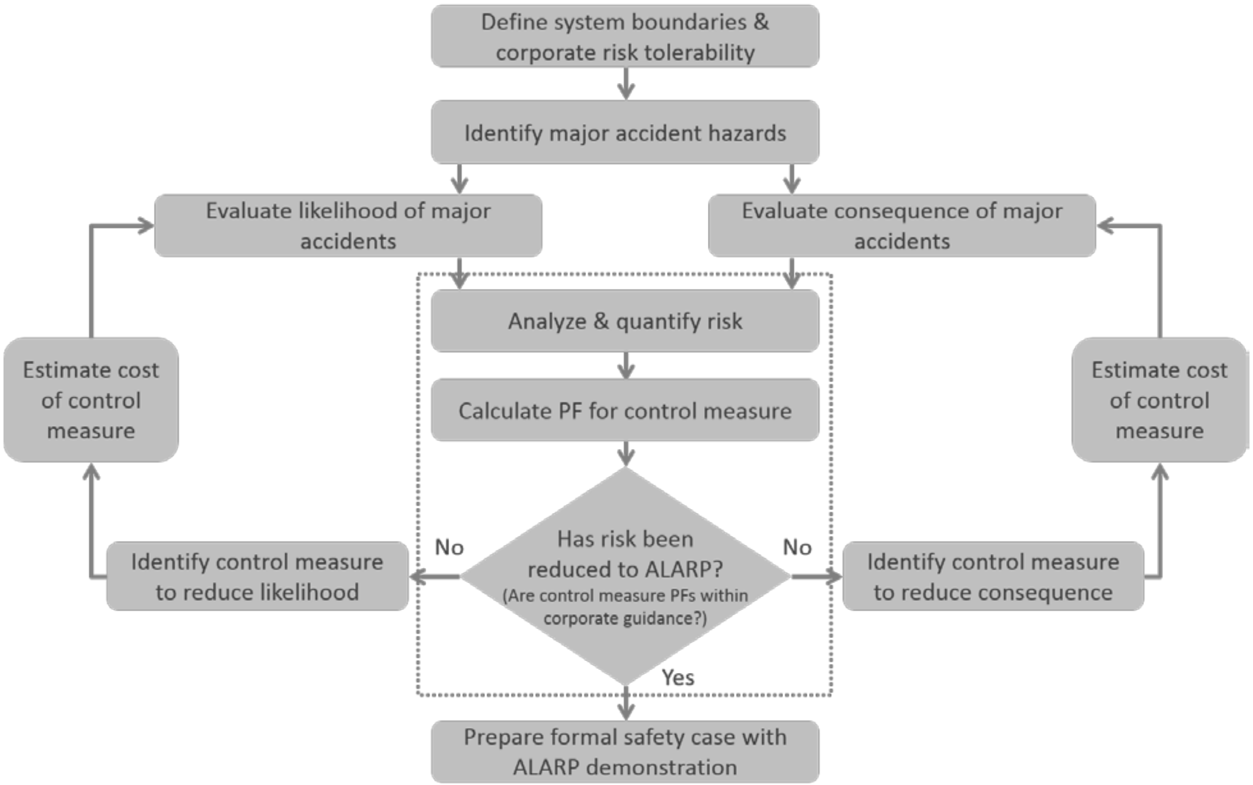


Figure 12. Notional ALARP Process

HSE inspectors review the Safety Case reports in detail and raise issues, as needed. The inspectors never formally accept the reports. The most that the HSE will concede is that they will not be raising more questions regarding the report, but that they will hold follow-up inspections addressing specific issues that they have identified in the reports. The HSE inspectors are obliged to inform the dutyholders in advance of the topics they wish to address in more detail in the coming year. HSE requires dutyholders to submit a Safety Case whenever necessary to reflect changing knowledge and operational conditions or at least every five years. Table 4 provides summary information about the program.

3.1.2. Program Overview

Table 4. HSE Safety Case: Program Attributes

Attribute	Description
Origin Date	**2005** – Implementation of Offshore Installations (Safety Case) Regulations
Analytical Complexity	**Various** – ranges from simple to highly sophisticated based on the inherent risk and complexity of the specific operation
Program Maturity	**High –** regulatory approach has been iteratively refined since 1974. Program does not require a mature set of accumulated historical risk data (industry is responsible for collecting the majority of the supporting data)
Frequency of Use	**On Demand** – during design of new installations and in advance of major modifications to existing installations, or at least every five years

Attribute	Description
Risk Management Support to Mission Scope	**Broad** – Safety Case tailored to address risks associated with HSE's mission to prevent and mitigate major offshore accident hazards
Government Level of Effort	**Low** – Risk analysis is performed by industry while government personnel serve in a review capacity
Key Context Factors	See Appendix F.7 for additional details: • **Industry Scale:** Medium – Approximately 320 facilities • **Political Factors:** Ubiquitous national application/support of Safety Case methodology • **Agency Maturity:** High – Agency faces staffing difficulties for highly technical Safety Case review positions
Point of Contact	**Susan Mackenzie,** susan.mackenzie@hse.gsi.gov.uk
Key References	• The Offshore Installations (Safety Case) Regulations 2005 • A Guide to the Offshore Installations (Safety Case) • Assessment Principles for Offshore Safety Cases (APOSC) • HID Regulatory Model: Safety Management in Major Hazard • HSE Information Sheet: Guidance on Risk Assessment for Offshore Installations

Figure 13 provides an overview of the HSE Safety Case risk management program by identifying the key inputs to the analysis process, the models used, the outputs of the models, and the decisions informed by the analysis. Table 5 provides details about each element presented in the figure.

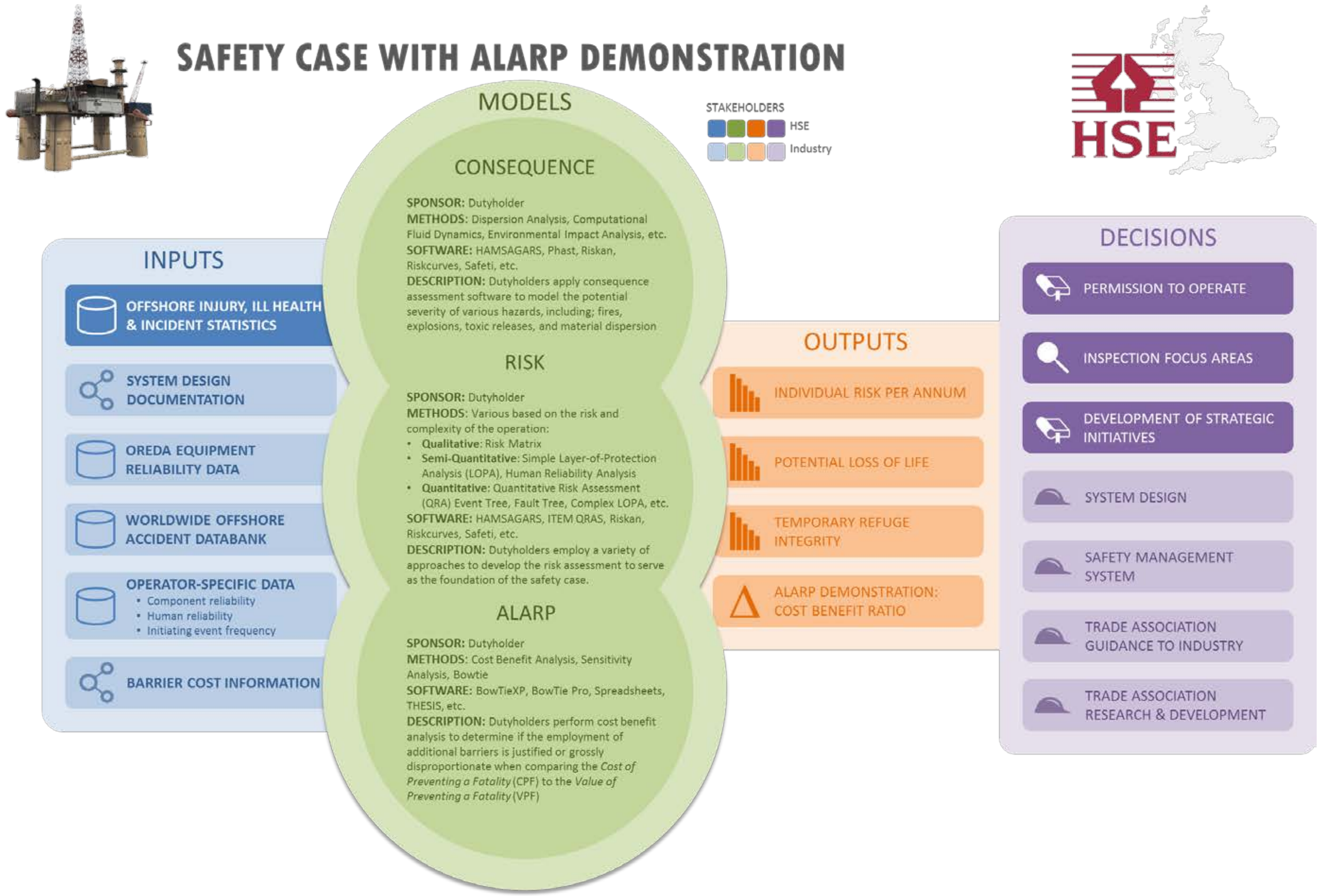


Figure 13. HSE Safety Case: Program Overview

Table 5. HSE Safety Case: Program Details

HSE Safety Case: Program Details	
INPUTS	
Name	**Description**
Government	
Offshore Injury, Ill Health & Incident Statistics	**Type:** Database & Report **Source:** HSE **Description:** Database and annual trend summary report of dangerous occurrences including hydrocarbon releases. The collected data are reported under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) initiated in 1995. Specific RIDDOR categories for offshore operations include: • Hydrocarbon release • H2S, or other harmful gases, release • Dropped object • Weather damage • Collisions • Evacuations • Falls into water > 2 meters
Industry	
System Design Documentation	**Type:** Various design documents **Source:** Dutyholder's engineers and designers **Description:** Structural and system designs plans used for establishing the safety significance of existing hazards and barriers.
OREDA Equipment Reliability Data	**Type:** Database **Source:** Industry Cooperative Program **Description:** The OREDA database and handbook contain aggregated equipment failure, maintenance, and operational data collected by eight large petroleum producing companies.
Worldwide Offshore Accident Databank (WOAD)	**Type:** Commercial Database **Source:** DNV-GL **Description:** DNV-GL is a commercial enterprise that maintains the WOAD database. The database contains 40 years of offshore accident data, systematically aggregated from a variety of sources, including: authorities, official publications and reports, newspapers, other databases, and rig owner/operators. These data can be used for assessing risk, developing emergency plans and safety procedures, and modeling production regularity and revenue.
Operator-specific Data	**Type:** Various **Source:** Operator Experience **Description:** The Safety Case methodology ultimately relies on the dutyholder to develop a sound argument for why no further risk barriers are required. Although standard industry models, data, and assumptions may contribute to the soundness of a Safety Case, operators are obliged to demonstrate why whatever data, expert opinions, reports, or models are specifically applicable to their case.
Barrier Cost Information	**Type:** Custom Design Cost **Source:** Vendors, Engineers, Designers, etc. **Description:** ALARP requires that the dutyholder demonstrate that an additional risk barrier would be disproportionately costly to the benefits from implementing it. Reliable estimates of the cost of such barriers are a critical input to this cost-benefit formulation.

<table>
<tr><th colspan="2">HSE Safety Case: Program Details</th></tr>
<tr><td colspan="2">MODELS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td colspan="2">No government models associated with this program.</td></tr>
<tr><td colspan="2">Industry</td></tr>
<tr><td>Consequence</td><td>Dutyholders must assess consequences estimating the potential severity of various major accident hazards, including fires, explosions, toxic releases, and material dispersions.
• Methods: The duty holder can employ a variety of methods to estimate the potential consequence of major accidents. The sophistication of the method should match the complexity and risk of the operation. Specific methods, include: Dispersion Analysis, computational Fluid Dynamics, Environmental Impact Analysis
• Software: There are a wide variety of commercial software packages to support consequence analysis. Some leading tools are HAMSAGARS, Phast, FRED, Riskan and Riskcurves.</td></tr>
<tr><td>Risk</td><td>Dutyholders must assess the risk of major accident hazards which serve as the foundation of the Safety Case.
• Methods: Similar to consequence, the dutyholder can employ a variety of methods to estimate the risk and should match the complexity and risk of the operation ranging from qualitative (simple) to quantitative (sophisticated). Specific methods include:
o Qualitative: Risk Matrix
o Semi-Quantitative: Simple LOPA, Human Reliability Analysis
o Quantitative: QRA, ETA, FTA, Complex LOPA, etc.
• Software: There are a wide variety of commercial software packages to support risk analysis. Some leading tools are HAMSAGARS, ITEM QRAS, Riskan, SHEPHERD, Riskcurves, and Safeti.</td></tr>
<tr><td>ALARP</td><td>Dutyholders perform cost benefit analysis to determine if the employment of additional barriers is justified or grossly disproportionate when comparing the Cost of Preventing a Fatality (CPF) to the Value of Preventing a Fatality (VPF).
• Methods: The dutyholder can employ a variety of methods to demonstrate ALARP, including: Cost Benefit Analysis (CBA), Sensitivity analysis, and bowtie.
• Software: There are a wide variety of commercial software packages to support the select methods, including: BowTieXP, BowTie Pro, Spreadsheets, and THESIS.</td></tr>
<tr><td colspan="2">OUTPUTS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td colspan="2">No government outputs associated with this program.</td></tr>
<tr><td colspan="2">Industry</td></tr>
<tr><td>Individual Risk per Annum (IRPA)</td><td>This is the chance an individual becomes a fatality. For example, an IRPA of $1x10^{-3}$ would mean for each individual, every year, there is a 1 in 1000 chance of a fatal accident.</td></tr>
<tr><td>Potential Loss of Life (PLL)</td><td>This is proportional to the sum of all the IRPAs. PLL is related to IRPA by the relationship:

IRPA = PLL x fraction of time an individual is offshore per year/people on board (PoB)

For example, an installation with a PoB of 50 people, working 2 weeks on, 2 weeks</td></tr>
</table>

HSE Safety Case: Program Details	
	off (fraction of time offshore per year is 0.5) with each person having an IRPA of 1×10^{-3} then the PLL would be 10^{-1} [10^{-3} x 50/0.5]. This means that a fatality would be expected on the installation on average once in every 10 years
Temporary Refuge Integrity (TRI)	This is the chance per year that the temporary refuge (TR) will be unable to perform in the way stated in the Safety Case. It is represented as a frequency per year, with an upper bound of no higher than 1×10^{-3}. This means that no more than once in every 1000 years would there be an event that would prevent the TR from functioning as described in the Safety Case.
ALARP Demonstration: Cost Benefit Ratio	The PF represents the ratio of the CPF divided by the VPF. If the PF is greater than 10, the cost of the additional barrier is generally considered "grossly disproportionate".
DECISIONS	
Name	**Description**
Government	
Permission to Operate	For new installations or for major modifications to existing installations, HSE must review and accept the dutyholder's Safety Case prior to operation.
Inspection Focus Areas	HSE reviews the information contained in the Safety Case, such as the planned safeguards, to help inform the focus areas for their inspections.
Development of Strategic Initiatives	HSE periodically reviews broad sets of Safety Cases to help identify common major issues across dutyholders. In some cases, these result in government-sponsored strategic initiatives where the issues are studied in detail.
Industry	
System Design	The Safety Case process helps inform the dutyholder's system design by ensuring that the design's risk is ALARP.
Safety Management System	The Safety Case process helps inform the dutyholder's Safety Management System by ensuring that the system's risk is ALARP.
Trade Association Guidance to Industry	Trade associations will periodically address common major issues identified by dutyholders. In some cases, these result in trade association-sponsored guidance to address the issues.
Trade Association Research & Development	Trade associations will periodically address common major issues identified by dutyholders. In some cases, these result in trade association-sponsored research and development initiatives where the issues are studied in detail.

The Safety Case regime is interesting in that the risk modeling is performed by industry. Because of this, when HSE receives a report, data *and* information are being collected, rather than just simply data. It remains for the regulator to critically review the report, sometimes even breaking down the outputs into data-level components. This process of checking the outputs is itself resource-intensive and requires highly skilled analysts and engineers to process and understand the data.

From HSE's point of view, the task of analyzing a Safety Case is akin to analyzing medium-volume, high-variety data (Figure 14). The large number of UK facilities contributes to the significant volume of Safety Cases. Among the countries in the International Regulators' Forum (IRF), only Mexico and the U.S. have jurisdiction over more facilities than the UK. Safety Case reports are not especially time-sensitive and are only updated every five years. Thus, data velocity is low.

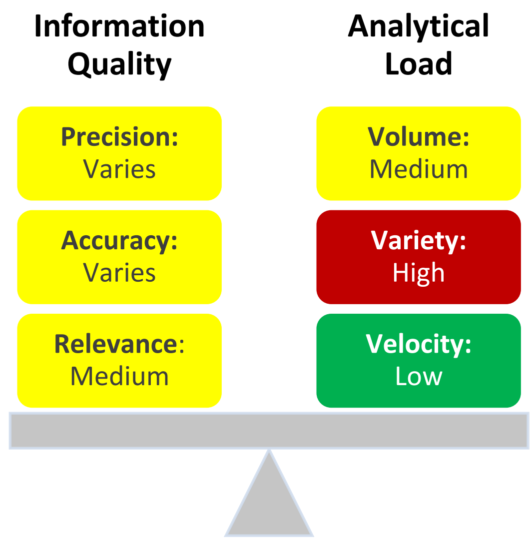


Figure 14. HSE Safety Case: Information Quality vs. Analytical Load

Safety Cases are, by definition, relevant to permissioning. They are also extremely relevant for understanding the risk level and risk-management strategy at a given platform. However, the high variety of information and data included in Safety Cases makes them difficult to compare across platforms or operators. Safety Cases provide little help for assessing overall industry risk levels. This blend of extreme relevance on an individual platform level and minimal relevance on an industry-wide level makes Safety Cases of "medium" relevance.

Unfortunately, because Safety Cases are unique to a platform, the level of accuracy and precision of the data presented may vary between Safety Cases. Furthermore, critics of the Safety Case approach claim that the approach promotes confirmation bias (acceptance of assumptions or errant values that support the desired conclusion).[10]

The Safety Case approach does not provide risk information to support a wide variety of government decisions. This is by design. The performance-based philosophy purposefully takes a hands-off approach with the intent of making industry as responsible for managing risk as possible.

3.1.3. Conclusions

Multiple IRF countries (Australia, Denmark, and New Zealand) have developed Safety Case regimes similar to what is used in the UK. Below are the key features and takeaways of this program:

- Decreasing production volumes present
- Pressure to increase production
- Aggressive exploration

[10] http://sunnyday.mit.edu/SafetyCases.pdf

- Many aging facilities seeking to extend useful life
- Potential weakening of HSE oversight
- Performance-based regulatory philosophy
- Defined risk tolerance criteria
- Duty to protect workers rests on industry
- Data and models managed by industry
- Safety Cases inform relatively few government decisions
- To make facility designs safer, Safety Cases must be implemented prior to facility construction
- Highly skilled staff are required to analyze Safety Cases

3.2. PSA RNNP

Since 2004, PSA has regulated offshore health, safety, and environmental functions in Norway. Prior to 2004, the Norwegian Petroleum Directorate (NPD) had responsibility over these functions as well as the administration of industry leasing and fee collection. These roles were separated in 2004 to remove potential regulatory conflicts of interest. PSA and NPD now maintain independent operations offshore, similar to BSEE's relationship with the Bureau of Ocean Energy Management (BOEM).

As one of the world's largest offshore petroleum producers and in the extreme environments of the North Sea and Arctic, Norway has sustained a remarkable safety record. Like HSE, PSA uses a performance-based approach to regulation, though significant prescriptive elements set it apart. Rather than pure application of Safety Case and ALARP, Norway requires permissioning applications to address certain risks in specific ways. For example, Norwegian law requires use of specific safety critical equipment, even if an HSE-style Safety Case might allow an alternative barrier of equivalent risk. In addition, the application of ALARP or other risk tolerance standards is less well defined.

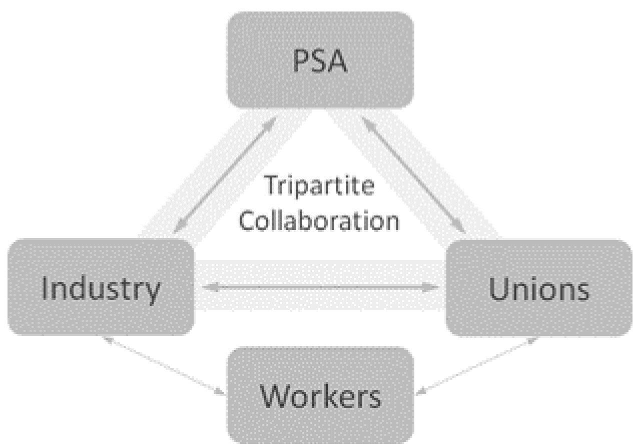


Figure 15. Tripartite Collaboration

Norway's system is most notable, not for its performance-based methodology, but for its strong ties to industry. The strength of the regulatory regime is buoyed by the influence of Norway's robust labor unions. The labor unions opposed the operators' claims of improved safety levels in the 1990s. In the midst of this debate, PSA (then NPD) took on a mediator role between industry and the unions. In this process, industry agreed to voluntarily report more information, such as near misses, as concessions to union demand. Figure 15 illustrates how PSA's involvement in the "tripartite" structure gives PSA more access to data and enables a more balanced understanding of issues on the worker level. Tripartite Collaboration improves both the relevance and the accuracy of Norway's data collection without dramatically increasing the volume of data to be analyzed.

Although the late 1990s and early 2000s marked the transition of PSA (NPD) to being a highly collaborative regulator, collaboration with Industry has long been intact. In 1981, Norway initiated the Offshore Reliability Data (OREDA) handbook in cooperation with eight large oil companies. This handbook has become an industry standard source for reliability data relating to equipment offshore. Since 2008, the handbook has adopted the equipment taxonomy used by ISO standard 14224, making it even more applicable on a worldwide scale.

For additional details regarding the PSA's operations and regulatory context, see Appendix F.9.

3.2.1. Program Overview

The objectives of the RNNP are to:

- Measure the status of the industry's health, safety, and environmental conditions.
- Contribute to identifying areas that are critical for HSE and where the effort to identify causes must be prioritized in order to prevent undesirable incidents and accidents.
- Increase insight into potential causes of accidents and their relative significance for the risk profile (e.g., to provide a better basis for decisions for the industry and authorities concerning preventive safety and emergency preparedness planning).

Table 6 provides summary information about the program.

Table 6. PSA RNNP: Program Attributes

Attribute	Description
Origin Date	**2000**
Analytical Complexity	**Simple** – RNNP is based on statistical analysis of reported data and worker surveys
Program Maturity	**High –** A robust set of historical data supports the program. The RNNP report is widely used as a reference tool for both the government and industry.
Frequency of Use	**Annual**
Risk Management Support to Mission Scope	**Broad** – RNNP addresses risk factors spanning PSA's oversight responsibilities of safety, emergency preparedness and the working environment in the Norwegian petroleum industry
Government Level of Effort	**Medium** – Annual analysis and report prepared by government representatives. Government also sponsors a biannual worker survey
Key Context Factors	See Appendix F.9 for additional details: • **Industry Scale:** Medium – Although Norway only has about 100 platforms, it also has about 300 subsea production facilities, enabling large production volumes. • **Political Factors:** Tripartite Collaboration • **Agency Maturity:** High – PSA was created in 2004, and has many responsibilities and programs carried over from NPD functions
Point of Contact	**Finn Carlsen,** finn.carlsen@ptil.no
Key References	• RNNP Website (in English) • 2013 RNNP Summary Report (in English)

Figure 16 provides an overview of the PSA RNNP program by identifying the key inputs to the analysis process, the models used, the outputs of the models, and the decisions informed by the analysis. Table 7 provides details about each element presented in the figure.

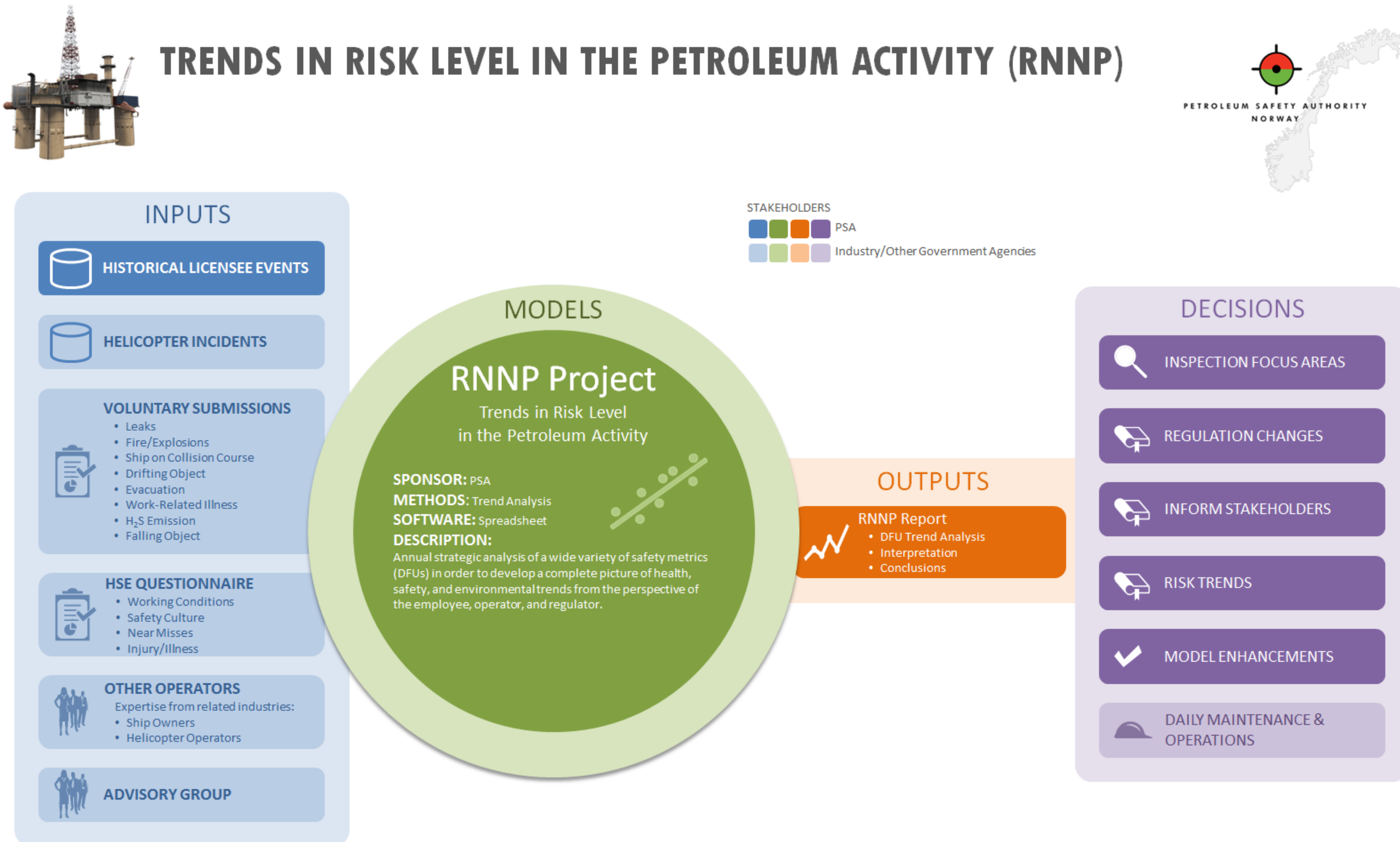


Figure 16. PSA RNNP: Program Overview

Table 7. PSA RNNP: Program Details

<table>
<tr><th colspan="2">PSA RNNP: Program Details</th></tr>
<tr><td colspan="2">INPUTS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td>Historical Licensee Events</td><td>Type: Databases
Source: Regulatory Submissions
Description: The PSA requires submission of certain incidents. Some of these incidents are classified as DFUs (defined hazard and accident conditions) and are used in the development of the RNNP report. Nine DFUs are used in the report and are shown below under the source database in which they are stored.
• Corrosion and Damage Database (CODAM)
o Damage to subsea production equipment/pipeline systems/diving equipment caused by fishing gear
o Leaks from subsea production facility/pipeline/riser/wellstream pipeline/loading buoy/loading hose events.
o Damage to platform structure/stability/anchoring/positioning fault
o Collisions with field-related vessel/facility/shuttle tanker
o Full loss of power
o Man over board
• Daily Drilling Report System (DDRS): Well incident/loss of well control
• PIP: Personal injury events
• DSYS: Diving accidents</td></tr>
<tr><td colspan="2">Industry</td></tr>
<tr><td>Helicopter Incidents</td><td>Type: Database
Source: Helicopter Operators, Civil Aviation Authority
Description: Helicopters are used extensively for transporting workers to and from production platforms; therefore, the safety of helicopter operations is an important consideration. Helicopter incidents reflect the safety of transporting crews to production platforms, even when the incidents are not specifically related to that task.</td></tr>
<tr><td>Voluntary Submissions</td><td>Type: Voluntary Reporting
Source: Owner/Operators
Description: A significant number of DFUs used in the RNNP report are not legally required to be reported on, but are supplied by industry to the PSA through informal cooperation between the operators and the regulator. These include:
• Non-Ignited Hydrocarbon Leak
• Ignited Hydrocarbon Leak
• Fire/Explosion in Other Areas, Combustible Liquid
• Ship on Collision Course
• Drifting Object
• Evacuation (Precautionary/Emergency Evacuation)
• Work-Related Illness
• H_2S Emission
• Falling Object</td></tr>
</table>

PSA RNNP: Program Details	
Health, Safety, & Environment Questionnaire	**Type:** Survey Data **Source:** Employees **Description:** Every two years, workers operating in PSA's jurisdiction are surveyed in order for the PSA to make sure that the employees and operators are in agreement about industry trends. The survey covers the following broad topics: • Working Conditions • Safety Culture • Near Misses • Injury/Illness
Other Operators	**Type:** Experts **Source:** Industry **Description:** Throughout the project, experts from related industries help provide guidance in areas where the PSA does not have sufficient data or expertise. • Ship Owners • Helicopter Operators
Advisory Group	**Type:** Experts **Source:** Various **Description:** Experts in risk analysis and in offshore oil production oversee the development of the RNNP project.
MODELS	
Name	**Description**
Government	
Trends in Risk Level in the Petroleum Activity	The RNNP model takes a broad look at all major risk factors related to offshore petroleum production. It is built on the understanding that a deep understanding of how to minimize risk as reflected by standard industry safety metrics such as frequency of lost-time incidents may overlook significant other areas of risk exposure. Additionally, the model seeks to address issues of reporting bias by industry by collecting data from industry as well as employees of industry. Each of the many risk metrics collected is analyzed individually and in comparison with others in order to gain insights related to industry risk level. This annual strategic analysis covers a wide variety of safety metrics (DFUs) in order to develop a complete picture of health, safety, and environmental trends from the perspective of the employee, operator, and regulator. • **Methods:** The RNNP model is a large collection of trend analyses. • **Software:** The RNNP analysis does not require highly specialized software and no such software is referenced in the report documentation. Spreadsheet trending algorithms make up the majority of the analysis.
Industry	
No industry models associated with this program.	
OUTPUTS	
Name	**Description**
Government	
RNNP Report	The output of the RNNP is a comprehensive report (in Norwegian) presenting trends on all of the identified risk factors in Norwegian offshore oil production. In addition, the PSA releases a summary report in both Norwegian and English. The summary report does present detailed analysis, but summarizes trends for each risk factor and interprets emerging results from the prior year.
Industry	
No industry outputs associated with this program.	
DECISIONS	

PSA RNNP: Program Details	
Name	**Description**
Government	
Inspection Focus Areas	The PSA can use the factors identified in the RNNP to prioritize the use of inspection resources.
Regulation Changes	New regulation can be written to target risk areas that are perceived as too high.
Inform Stakeholders	Stakeholders in the petroleum industry are the operators, unions, regulators, and other related industries, but also include the national legislature. RNNP serves as a tool for accounting for the impact that the PSA has been charged by the legislature to produce.
Risk Trends	PSA evaluates and communicates trends in a suite of risk factors to industry to inform their operations.
Model Enhancements	The PSA gathers feedback from each iteration of the RNNP and adjusts the contents of the health, safety and environmental questionnaires in order to gain more insight into areas that had been identified as lacking. Once a significant risk factor is identified, future iterations of the RNNP will highlight these factors.
Industry	
Daily Maintenance & Operations	Through PSA events such as the Safety Forum and Regulatory Forum, the priorities outlined in the RNNP are promoted before representatives of operators and unions so that the most significant risk drivers can be addressed in daily operations.

The RNNP reviews data from a number of databases containing industry incident and reporting data as well as data collected specifically for the project, including near-miss data and worker survey results. The RNNP contains a significant amount of data from a wide variety of sources. Neither the volume nor variety of data is extraordinarily high (Figure 17). However, if the PSA had jurisdiction over a larger number of facilities, the data volume could reach the “high” category. The RNNP is published annually, so data velocity is low.

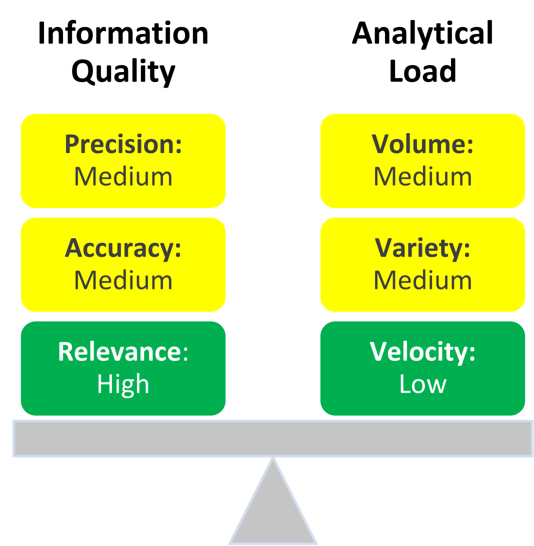


Figure 17. PSA RNNP: Information Quality vs. Analytical Load

The RNNP program’s information quality stands out in the offshore industry for producing quality information. Tripartite Collaboration is certainly a driver of this success. PSA has ability to corroborate industry’s self-assessment of risk with the worker’s assessment of risk. This drives data accuracy. Output information is directly relevant to decreasing risk through improved communication and cooperation of industry, workers, and government as well as through better understanding of risk drivers. The precision of the information output is sufficient for its general decision-making purpose.

3.2.2. Conclusions

PSA maintains a unique regulatory regime:

- Large oil producer
- Relatively few platforms (~100)

- Many subsea installations (~300)
- Performance-based philosophy
- Prescriptive elements surrounding required safety-critical systems.
- Strong union influence
- Regime built on collaboration and communication among industry, unions, workers and government
- Data supplied by industry
- Analysis and modeling performed by government
- High quality output, targeted to support safety improvement

3.3. NRC Risk-Informed Regulations and Inspections Program

The NRC regulates nuclear power plants in the U.S. Although there are only about 100 commercial nuclear power plants within NRC jurisdiction, the industry is of great concern to the American public due to the catastrophic consequence potential of accidents resulting in major federal spending on risk management. Risk management processes focus primarily on reducing the likelihood of reactor core damage (e.g., meltdown). The relative narrow focus of preventing core damage coupled with a large analytical budget has allowed the NRC to develop the most sophisticated government risk management program over the last several decades. The NRC’s continuous onsite inspection of each facility makes enforcement relatively straightforward.

Regulatory oversight has shaped the nuclear industry. Instead of putting emphasis on new, previously untested technologies, the regulatory framework stresses refining and developing a thorough understanding of existing processes and the impact that day-to-day maintenance has on each facility’s likelihood to suffer reactor core damage. After decades of collecting data, developing models, and gaining regulatory experience in an industry that has not been allowed to change quickly, the NRC is an example of a very mature regulatory agency.

3.3.1. Program Overview

The NRC has developed a comprehensive risk analysis and management program to help them make continuing, incremental improvements in rulemaking, licensing, and oversight of operating reactors, while focusing on implementing existing risk-informed and performance based activities. The NRC has employed a deliberate process to develop a mature program with the following characteristics:

- The current risk-informed initiatives help to improve the effectiveness and efficiency of the NRC's regulatory process, including improved safety and reduction of unnecessary regulatory burden.
- Tailored probabilistic risk assessment (PRA) models exist for all U.S. commercial operating reactors and are fairly mature.
- The cost-beneficial nature of several of the risk-informed initiatives is evidenced by their voluntary adoption by licensees.
- No factors have been identified to date that would motivate changing the regulatory approach in the areas where risk-informed activities are already underway. Stakeholder feedback substantiates that there is no immediate need to initiate any new risk-informed initiatives, and that the NRC should focus on completing currently identified activities and allowing the industry time to implement those activities.

- Goals and activities are performance-based to the extent that they meet these criteria:
  - Measurable parameters to monitor performance
  - Objective criteria to assess performance
  - Flexibility to allow licensees to determine how to meet the performance criteria
  - No immediate safety concern as a result of failure to meet the performance criteria

The NRC has developed Standardized Plant Analysis Risk (SPAR) models that provide a consistent analytical framework for their risk-informed regulations and inspections program. SPAR models are plant-specific PRA models that model accident sequence progression, plant systems and components, and plant operator actions. The standardized models represent the as-built, as-operated plant. The SPAR models permit the NRC staff to perform risk-informed inspection activities by independently assessing the risk of events or degraded conditions at operating nuclear power plants. They also support NRC inspectors by prioritizing their inspection activities and characterizing the significance of their inspection findings.

In addition to the government-developed SPAR model program, NRC regulations require that licensees develop and maintain their own independent PRA models to inform the daily operations and maintenance of their plants.

Table 8 provides summary information about this comprehensive risk management program spanning both government and industry.

Table 8. NRC Risk-Informed Regulations and Inspections: Program Attributes

Attribute	Description
Origin Date	**1994** – NRC leadership formally issued the *Proposed Agency-Wide Implementation Plan for PRA* (SECY-94-219), which led to the development of the program as it is today.
Analytical Complexity	**Complex** – Program employs very sophisticated PRA models for a range of accident initiating events.
Program Maturity	**High –** NRC has been iteratively improving PRA capabilities since the mid-1970s. Models are supported by a robust set of historical data.
Frequency of Use	**Continuous** – Models are used continuously by industry and government to inform short and long-term decisions
Risk Management Support to Mission Scope	**Broad** – Risk information is used to support a broad array of NRC's regulatory and inspection decisions
Government Level of Effort	**Very High** – Government representatives maintain the SPAR models, perform analyses, and review industry-performed risk analyses.
Key Context Factors	• **Industry Scale:** Low – About 100 facilities • **Political Factors:** Significant public fear of nuclear threats. Support for extensive regulation. • **Agency Maturity:** High – Technology has developed slowly, allowing the NRC to gain solid handle on industry.
Point of Contact	**Don Marksberry,** Don.Marksberry@nrc.gov
Key References	• Risk Assessment in Regulation • History of the NRC's Risk-Informed Regulatory Programs • Regulatory Guide 1.174 – PRA Guide for Plant-Specific Changes to the Licensing Basis • Significance Determination Process

Figure 18 provides an overview of the NRC Risk-Informed Regulations and Inspections Program by identifying the key inputs to the analysis process, the models used, the outputs of the models, and the decisions informed by the analysis. Table 9 provides details about each element presented in the figure.

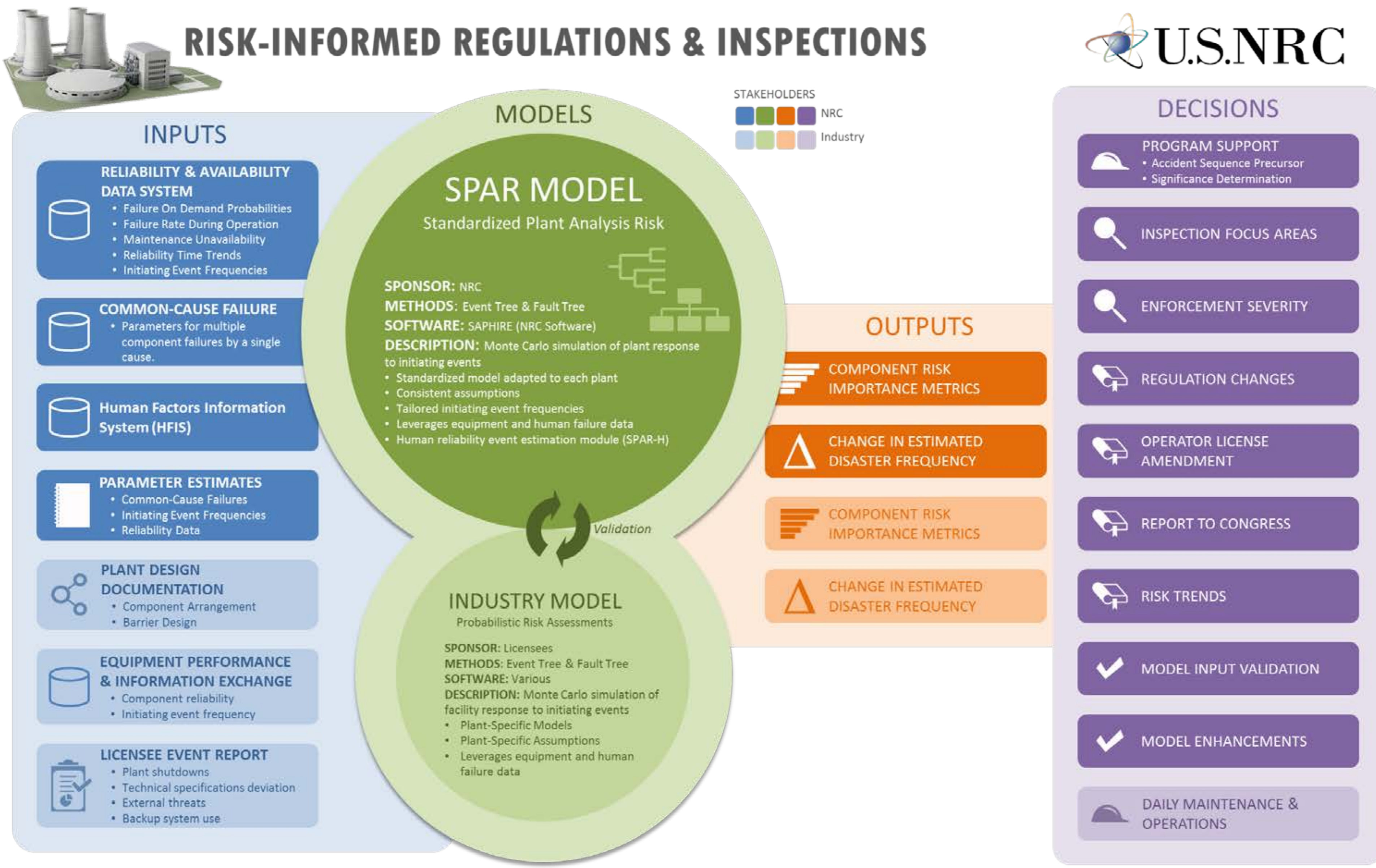


Figure 18. NRC Risk-Informed Regulations and Inspections: Program Overview

Table 9. NRC Risk-Informed Regulations and Inspections: Program Details

NRC Risk-Informed Regulations and Inspections: Program Details	
INPUTS	
Name	**Description**
Government	
Reliability & Availability Data System (RADS)	**Type:** Database **Source:** Institute of Nuclear Power Operations (INPO) Equipment Performance Information Exchange System (EPIX) and other sources **Description:** RADS is a database and analysis tool designed to estimate industry and plant-specific reliability and availability parameters for selected components in risk-important systems for use in risk-informed applications. RADS contains data and information based on actual operating experience from EPIX. The information covers reliability/availability data from 1997 and initiating event data from 1987. Because EPIX data are proprietary, NRC provides the RADS database and the RADS analysis software to NRC staff and nuclear power plant licensees who are members of INPO. The reliability parameters estimated by RADS are as follows: • Failure on-demand probabilities • Failure rate during operation • Maintenance unavailability • Reliability time trends • Initiating event frequencies
Common Cause Failure (CCF) Database (CCFDB)	**Type:** Database **Source:** EPIX and Licensee Event Reports (LERs) **Description:** The CCFDB is a data collection and analysis system that includes a method for identifying CCF events (multiple component failures by a single cause), coding and classifying those events for use in CCF studies, and a computer system for storing and analyzing the data. Three data sources are used to select equipment failure reports to be reviewed for CCF event identification: (1) the Nuclear Plant Reliability Data System (NPRDS), which contained component failure information prior to 1997, (2) EPIX, and (3) the Sequence Coding and Search System (SCSS), which contains LERs. Because NPRDS and EPIX data are proprietary, NRC provides the CCFDB and the CCF analysis software to NRC staff and nuclear power plant licensees who are members of INPO. The CCFDB is used to obtain CCF parameter estimates for use in PRAs and risk studies.
Human Factors Information System (HFIS)	**Type:** Database **Source:** LERs **Description:** NRC uses HFIS information to assist in its programmatic oversight of training procedures, organizational processes, human-system interface, communication, and inspections. The information in the HFIS database is not considered all-inclusive but rather indicative of overall performance at an individual plant. The information is intended to provide a general overview of the types and approximate numbers of performance issues documented in these reports. The data in HFIS represent reports issued from 1997 in the following areas: • Training • Procedures and Reference Documents

NRC Risk-Informed Regulations and Inspections: Program Details	
	• Fitness for Duty • Oversight • Problem Identification & Resolution • Communication • Human-System Interface and Environment • Work Planning and Practices
Parameter Estimates	**Type:** Reports **Source:** NRC Studies **Description:** The NRC produces a wide variety of parameter estimates. These values are made available to industry in summary form (rather than as large databases of individual incidents). Examples include: • CCF - summaries from the CCFDB • Initiating event frequencies (e.g., statistical and engineering analysis of Loss of Offsite Power event frequencies and durations) • Reliability data - component performance summaries for specific equipment, including: air-operated valves, emergency diesel generators, motor-operated valves, motor-driven pumps, and turbine-driven pumps
Industry	
Plant Design Documentation	**Type:** Various design documents **Source:** Licensee's engineers and designers **Description:** Structural and system designs used to inform development of the PRA models by describing functions, systems, and sub-systems included in the design of the plant.
EPIX	**Type:** Database **Source:** INPO Members **Description:** EPIX is an extensive database of component reliability and availability statistics and initiating event frequencies for transients, small loss-of-coolant accident (LOCA), medium LOCA, large LOCA, interfacing system LOCA, steam generator tube rupture, loss of offsite power, loss of component cooling water, loss of service water, and loss of direct current power.
Licensee Event Reports	**Type:** Report **Source:** Licensee **Description:** The NRC requires extensive reporting by the licensee in the case of any of these events: • Plant shutdowns • Technical specifications deviation • Barrier degradation • Unanalyzed condition • Component failures • External threats • Backup system use For each event, the licensee is required to document the failure mode and mechanism, effect, root cause, date and time, status of related structures at the time of failure, related systems and components, affected secondary functions, method of discovery of failure, failed component model numbers, availability of response systems, and planned corrective action.

<table>
<tr><td colspan="2">NRC Risk-Informed Regulations and Inspections: Program Details</td></tr>
<tr><td colspan="2">MODELS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td>SPAR Model</td><td>SPAR models are plant-specific PRA models that model accident sequence progression, plant systems and components, and plant operator actions. They represent the as-built, as-operated plant. They provide NRC staff with the capability to perform risk-informed regulatory activities by independently assessing the risk of events or degraded conditions, such as equipment outages at commercial nuclear power plants.
Methods: The SPAR models are built upon event tree/fault tree methodology, and they use Monte Carlo simulation of plant response to a variety of initiating events.
Software: SPAR models are built in the Systems Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE) software, which was developed by the Idaho National Laboratory (INL) for the NRC.</td></tr>
<tr><td colspan="2">Industry</td></tr>
<tr><td>Industry PRA Model</td><td>Licensees are required to develop and maintain their own PRA models to inform their daily operations.
Methods: This model is built upon event tree/fault tree methodology, and they use Monte Carlo simulation of plant response to a variety of initiating events.
Software: There are a number of commercial software packages available to licensees to support risk analysis. Some leading tools are CAFTA, RISKMAN, and RiskSpectrum PSA.</td></tr>
<tr><td colspan="2">OUTPUTS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td>Component Risk Importance Metrics</td><td>The SPAR models are capable of generating a variety of component-specific importance measures to help understand the safety importance of structures, systems, and components (SSCs). The importance metrics most commonly identified in the relative risk ranking of SSCs are:
Fussell-Vesely Importance of a SSC is defined as the fractional decrease in total risk level when the SSC is assumed perfectly reliable
Risk Reduction Worth (RRW) of a SSC is the decrease in risk if the SSC is assumed to be perfectly reliable. It is expressed in terms of the ratio of the baseline risk level to the risk with the SSC guaranteed to succeed.
Risk Achievement Worth (RAW) of a SSC is the increase in risk if the SSC is assumed to be failed at all times. It is expressed in terms of the ratio of the risk with the SSC failed to the baseline risk level.
Birnbaum measures are also used to provide a measure of how often a SSC is critical.</td></tr>
<tr><td>Change in Estimated Disaster Frequency</td><td>The SPAR models generate two summary metrics that describe the expected annual frequency of disasters based on the condition of the plant, specifically:
Core damage frequency (CDF) is the sum of the frequencies of those accidents that result in the reactor core being uncovered to the point at which significant damage to the core is anticipated.
Large early release frequency (LERF) is the frequency of those accidents leading to significant, unmitigated releases from containment in a time frame prior to effective evacuation of the close-in population such that there is the potential for early health effects.</td></tr>
</table>

NRC Risk-Informed Regulations and Inspections: Program Details	
	These metrics can be generated for baseline conditions or conditions when the plant is in a degraded status (e.g., equipment outages). For many applications, differences are calculated between the plant's baseline and degraded conditions (ΔCDF, ΔLERF) to determine the severity of the degradation. The NRC has established explicit quantitative risk-based acceptance criteria for a variety of decisions based on these metrics. Figure 19 provides an example of the risk acceptance guidelines for CDF and ΔCDF metrics.

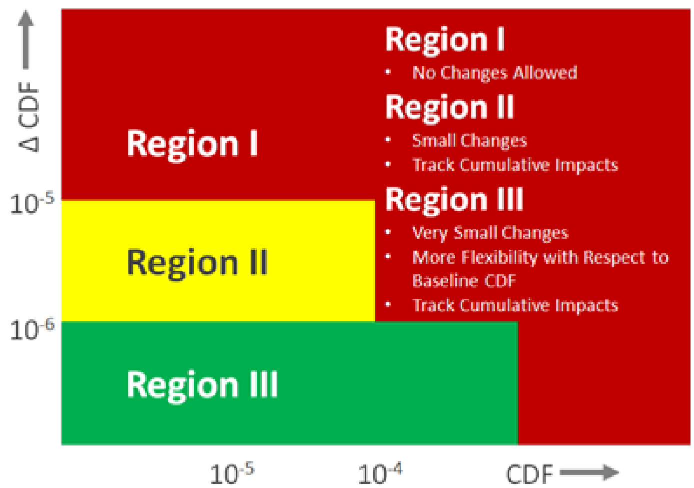


Figure 19. NRC Acceptance Guidelines for CDF and ΔCDF

Industry	
Component Risk Importance Metrics	Same as government metrics described above.
Change in Estimated Disaster Frequency	Same as government metrics described above.
DECISIONS	
Name	**Description**
Government	
Program Support	The comprehensive scope of the NRC's PRA models provides the capability for the NRC to model a wide variety of issues to support regulatory development and inspection activities. Often the NRC uses the models to support in-depth studies of specific issues.
Inspection Focus Areas	NRC inspectors rely on PRA models and results to: • Guide and prioritize their inspection activities based on plant-specific information • Characterize the significance of inspection findings • Provide all stakeholders with an objective and common framework for communicating the significance of inspection findings • Provide a basis for timely assessment and/or enforcement actions associated
Enforcement Severity	The NRC's enforcement program is based on the recognition that violations occur in a variety of activities and have varying levels of significance. PRA results are used to inform the NRC of the severity of the licensee violations.
Regulation Changes	NRC uses risk information to enhance their regulations by applying PRA models and results to identify/prioritize a broad set of potential safety issues, and evaluate the

NRC Risk-Informed Regulations and Inspections: Program Details	
	impact of a broad set of potential mitigation measures.
Operator License Amendment	Licensees can request amendments to the basis of their licenses by using PRA to demonstrate that the changes are within the NRC's risk acceptability criteria.
Report to Congress	NRC frequently provides reports to Congress summarizing the status of the commercial nuclear industry and addressing key issues.
Risk Trends	NRC routinely monitors and reports on indicators of nuclear industry performance to confirm that the safety of operating power plants is being maintained
Model Input Validation	NRC continually gathers feedback on the data inputs to the SPAR models to identify areas where further research or modeling is required to address identified gaps.
Model Enhancements	NRC continually gathers feedback on their SPAR models and validates their results with the licensee's PRA to inform future enhancements to their models.
Industry	
Daily Maintenance & Operations	Licensees employ their PRA models on a daily basis to understand the risk associated with their plant's status. They use PRA models as a critical input to their maintenance planning and operational decisions.

The NRC's SPAR model is one of the most analytically intense regulatory risk models in use. There are three groups of data (Figure 20). First, a large amount of plant design information is required to enable the construction of an ET/FT model of a given plant. Second, initiating event frequency data, component reliability, and human reliability estimates are inputs into the ET/FT model to enable Monte Carlo simulation of actual loss events. Finally, daily data are collected about the status of each individual plant so that the SPAR models can be used to maintain real time awareness of the risk of a loss event. The quantity of data of multiple different types contributes to the high volume of data required. The complexity of design documents and the different types of data lead to a high variety of data to be processed. Daily data handling contributes to medium data velocity. Only near continuous flow of new data into the model would be classified as high data velocity.

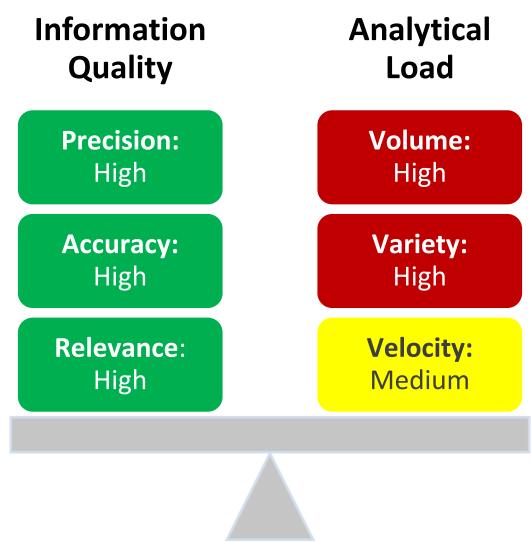


Figure 20. NRC ASP: Information Quality vs. Analytical Load

The analytical load of the SPAR model is justified by high quality data and information. In effect, the SPAR model builds a digital version of the plant, enabling sophisticated simulation to identify the most likely loss events and the components and systems involved. This information is highly relevant for regulation. Given the level of detail in the input data, SPAR models can produce highly precise output information. The accuracy or certainty of model output is high relative to other types of models. The caveat to a high accuracy/certainty assessment is that ET/FT models are only as comprehensive as the model builders. Often, failures or near misses that do occur are due to previously unrecognized failure modes and therefore are not well accounted for.

3.3.2. Conclusions

NRC maintains a robust regulatory regime over a small industry:

- Small industry (~100 commercial nuclear power plant)
- Highly public concern about risks of nuclear accidents
- Heavy regulation
- Performance-based regulatory metrics
- Slow-changing industry
- Robust data collection
- Redundant analysis by industry and government
- High-quality, high-precision information output
- Integrated application of information to inspections, regulations, and operations

3.4. NASA APA

NASA is not a regulatory agency, but performs a wide variety of high-risk operations. As such, it maintains controls to facilitate internal risk management.

Although each NASA operation may encounter similar risks, the vast amount of resources required for a single operation may prevent a single team from performing multiple operations. This isolation of individuals working on various operations creates the possibility that a risk that is discovered by one team may not be communicated to another operation's team, even if that risk is equally or more relevant to the second operation.

To overcome this challenge, NASA has developed a risk inventory program that spans all NASA research and programs regardless of the level of risk involved.

3.4.1. Program Overview

The APA process identifies and characterizes sources of safety risk to NASA's various operations. The process begins with the observation of an anomalous event. Even if the anomalous event fails to produce a significant risk to safety, it is taken as a potential accident precursor until it can be sufficiently studied and understood. An accident precursor signals the possibility of future, more severe consequences stemming from the failure mechanisms observed in historical anomalous events.

Their early identification allows them to be fully scrutinized and the results to be used to inform decisions relating to safety. Stemming from the anomalous event that was actually observed, the NASA process invokes an "imaginative" aspect to the process, using a structured brainstorming session to identify similar anomalous conditions that could have more severe consequences than the observed anomalous event. In the context of NASA systems, the term severe consequences typically refers to loss of crew, loss of vehicle, loss of mission, or loss of science. It is up to the particular program employing the approach to define severe consequences appropriate to its objectives and apply the technical approach accordingly.

The APA program is intended to overcome the siloed testing and failure data collection among each of NASA's many programs. Because of the wide variety of components and systems among these programs, the APA process is necessarily SME-intensive. At its foundation, the APA is a framework for checking that any performance anomaly observed, and perhaps even tested, within one program or system does not apply more widely in other areas of NASA research and operation. The end goal is that facilitation of understanding of these anomalies will prevent the scenario where an anomaly that is well documented and understood in one system would not be a cause of failure in another system, simply because it was not understood by the individuals involved in that other system. Figure 21 illustrates the APA process flow.

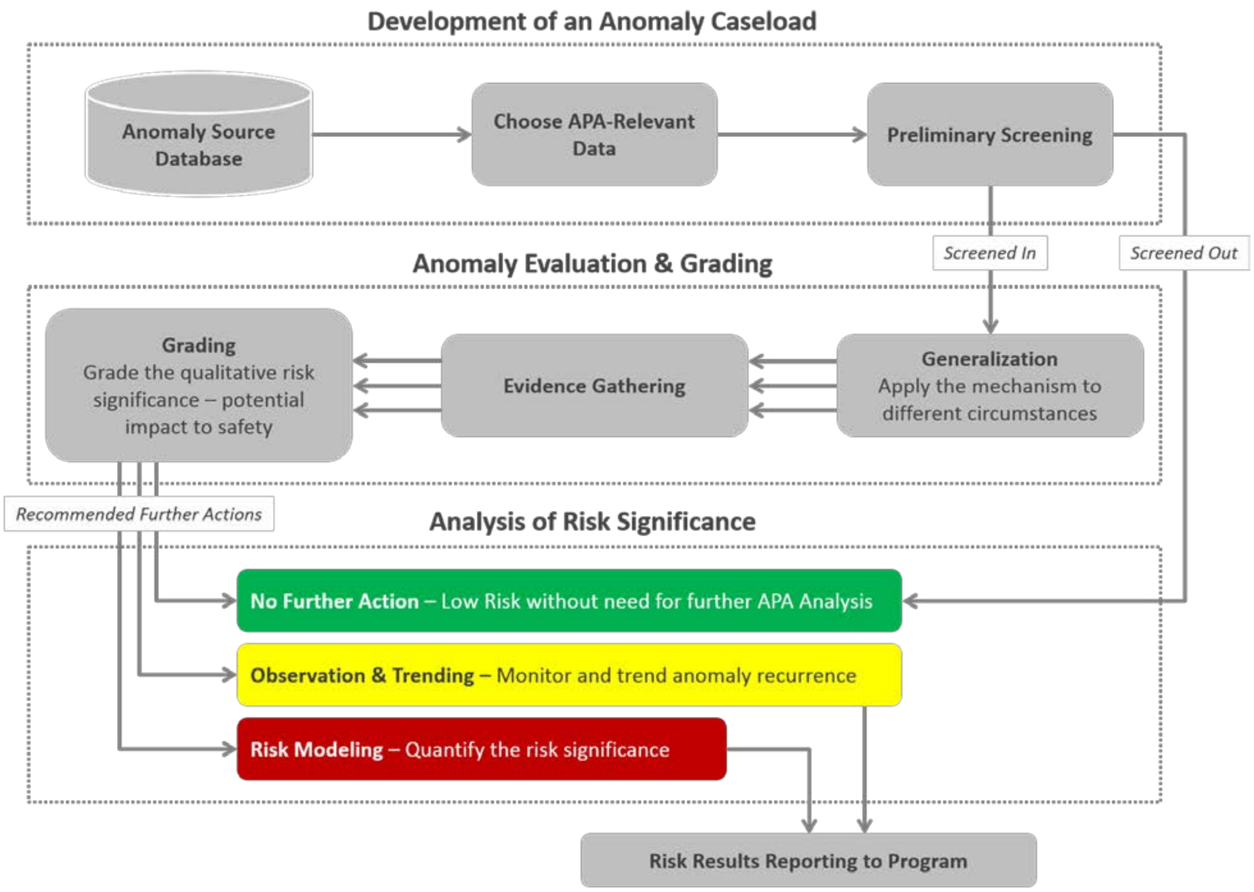


Figure 21. NASA APA Process Flow Diagram

The first step of the APA process is the selection of anomalies for review. Typically, one program's test data or failure database is selected for review. Next, a panel of SMEs sorts through the data, identifying anomalous events that it perceives might have significant applicability to other programs. For example, an anomalous event might be the failure of a rubber O-ring during testing at low temperatures. Any event that is deemed insignificant receives no further attention.

If the panel determines that the event may be significant, then it goes on to the next phase of the process: generalization. The event is separated into two parts, the anomalous condition or failure mechanism and the component performance under that condition. In the case of the O-ring, the failure mechanism would be the low temperature while the component performance would be the failure of the O-ring. The generalized anomalous condition is the key concern.

The panel of SMEs then collects evidence to determine what other NASA systems might be impacted by the anomalous condition. Risk is measured as the likelihood of failure given the anomalous condition combined with the likelihood of severe consequence given that failure of the component occurs.

If an anomalous condition has either high-likelihood of causing failure or leads to high-consequence when failure occurs but does not have both of these qualities, it is selected for continued observation and trending to see if future experiences will ever necessitate further analysis.

The anomalous condition has high risk if it is likely to cause failure and if that failure is likely to be high-consequence. In such a case, the anomalous condition is marked for detailed risk modeling, either through careful physics computation or statistical risk analysis.

Table 10 provides summary information about the NASA APA program.

Table 10. NASA APA: Program Attributes

Attribute	Description
Origin Date	**2007**
Analytical Complexity	**Moderate** – Complexity and sophistication of risk modeling employed varies depending on the perceived risk significance of the anomaly
Program Maturity	**Medium –** Version 1 of the APA Handbook was produced in 2011
Frequency of Use	**Routine** – Groups of anomalies are periodically evaluated for risk significance
Risk Management Support to Mission Scope	**Broad** – Analytical scope covers broad array of NASA mission types
Key Context Factors	• **Industry Scale:** N/A • **Political Factors:** Not a regulator but responsible to guard the safety of pilots and astronauts performing its operations • **Agency Maturity:** High – NASA has vast experience in its mission space
Government Level of Effort	**High** - All analysis performed by government representatives
Point of Contact	**Dr. Frank Groen**, Frank.J.Groen@nasa.gov
Key References	• NASA Accident Precursor Analysis Handbook • NASA System Safety Handbook

Figure 22 provides an overview of the NASA APA program by identifying the key inputs to the analysis process, the models used, the outputs of the models, and the decisions informed by the analysis. Table 11 provides details about each element presented in the figure.

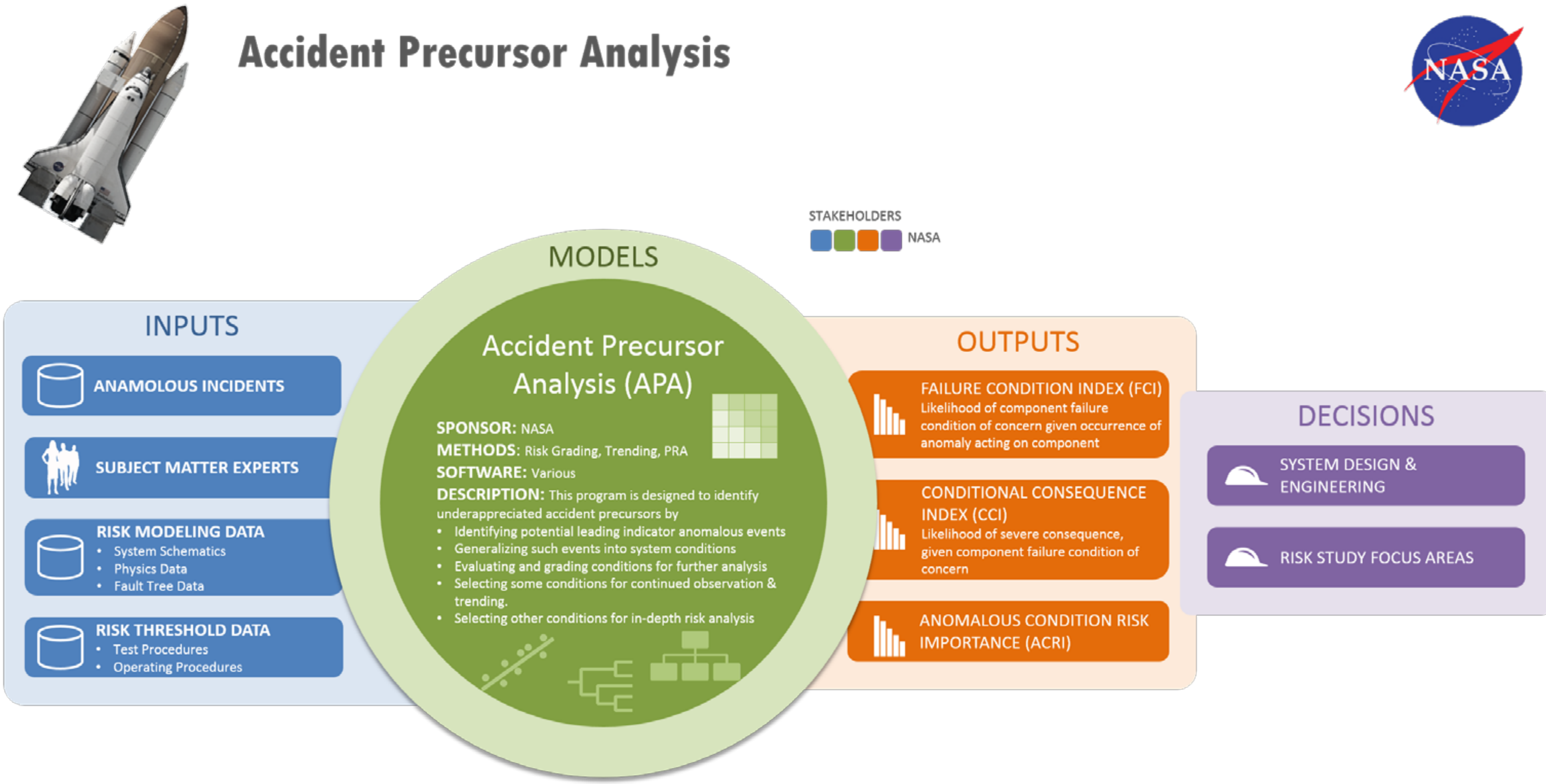


Figure 22. NASA APA: Program Overview

Table 11. NASA APA: Program Details

NASA APA: Program Details	
INPUTS	
Name	**Description**
Government	
Anomalous Incidents	**Type:** Various Databases **Source:** Various Failure Data Collection Programs **Description:** Anomaly Source Databases can be any of NASA's databases for collecting and documenting failure phenomena. The APA program is a way of consolidating and processing all of these data so that they can be applied generically across programs. Examples of anomalous incident data might include. • Post-flight inspection data • Failure observed in operation • Test data • Reliability databases
Subject Matter Experts	**Type:** SMEs **Source:** NASA Engineers **Description:** The APA program relies heavily on the opinions of the expert engineers, designers, and technicians to perform the screening stages as well as to design risk analyses specific to selected anomalies.
Risk Modeling Data	**Type:** Blue Prints/Schematics **Source:** System Features **Description:** If an anomaly is deemed to be of high importance, the system designs affected by the anomaly will need to be made available so that risk models can be developed. • System Schematics • Design Drawings • Physics Data • Fault Tree Data
Risk Threshold Data	**Type:** Various **Source:** Existing Protocols **Description:** The APA program might base its risk tolerance thresholds by leveraging information available in existing projects: • Test Procedures • Operating Procedures
Industry	
No industry data associated with this program.	
MODELS	
Name	**Description**
Government	
Accident Precursor Analysis (APA)	APA is designed to identify underappreciated accident precursors by: • Identifying potential leading indicator anomalous events • Generalizing such events into system conditions • Evaluating and grading conditions for further analysis • Selecting some conditions for continued observation & trending • Selecting other conditions for in-depth risk analysis **Methods:** Risk Grading, Trending, PRA **Software:** NASA research and development span a wide variety of scientific disciplines. Depending on the nature of the risk, it may be more or less important for software specific to a particular phenomenon (e.g., heat transfer) to be used. In other cases, PRA techniques may be required.

NASA APA: Program Details	
Industry	
No industry models associated with this program.	
OUTPUTS	
Name	**Description**
Government	
Failure Condition Index (FCI)	The likelihood of component failure of concern given occurrence of anomalous condition acting on the component.
Conditional Consequence Index (CCI)	The likelihood of a severe consequence, given that the component has failed.
Anomalous Condition Risk Importance (ACRI)	A qualitatively defined measure of the risk importance of the occurrence with respect to the benchmark system risk.
Industry	
No industry outputs associated with this program.	
DECISIONS	
Name	**Description**
Government	
System Design & Engineering	The APA model is primarily intended to support the design of systems by providing a database of potential failure mechanisms that a new design needs to address and protect against.
Risk Study Focus Areas	Anomalous conditions that have been determined to be high risk often require deeper study and risk modeling in order to make sure that all of NASA's programs, processes, and systems are adequately guarding against such risks.
Industry	
No industry decisions associated with this program.	

Most of the load of the analysis is due to pulling in risk data from various NASA programs and evaluating it (Figure 23). If a high risk is identified, any number of modeling techniques can be used to bring better understanding of the risk. Variety of analysis requires variety of supporting data. Certain risks may require large amounts of data for analysis, but others may require only expert opinion. The screening model is not receiving new data on any regular basis, so data velocity is low.

The key to the NASA approach is to allocate analysis resources according to the level of risk. High risk scenarios receive a lot of attention so that relevant data and information can be produced. Low risks are not very relevant, so appropriately small amounts of information are produced. Precision and accuracy may vary, but are generally sufficient for whatever risk is being analyzed.

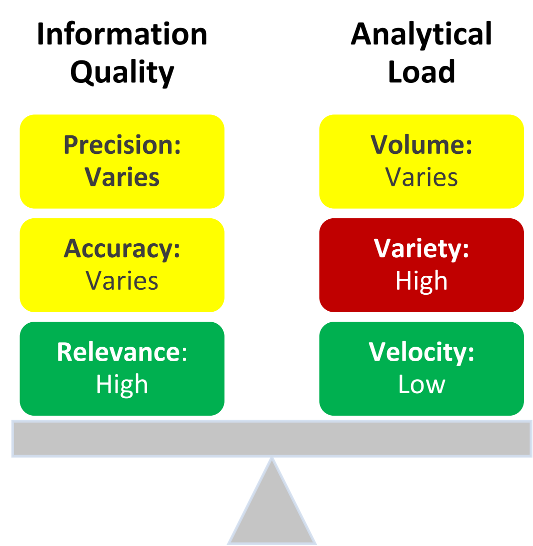


Figure 23. NASA APA: Information Quality vs. Analytical Load

3.4.2. Conclusions

NASA is not a regulatory agency, but has several compelling attributes.

- No industry. Used for internal controls
- APA is primarily a risk inventory and screening tool
- Fast-changing, high-risk technologies
- Supporting data from a variety of projects
- Analysis tools tailored to the level and type of risk
- Output informs risk understanding across all programs

3.5. USCG NMSRA

The USCG performs a wide array of activities across its 11 missions. Within each mission, there are a variety of unwanted events which can result in negative impacts to the American public. The diversity of demands competing for limited USCG multi-mission resources provides USCG decision makers with an exceptionally complex resource allocation problem. In addition, over the last several years, USCG decision makers have found it increasingly necessary to substantiate their resource allocation decisions.

For these reasons, the USCG has been steadily building, over the course of many years, its risk analysis and risk management capabilities, beginning with the rollout of the USCG Risk-Based Decision-Making (RBDM) Guidelines. The wide array of risk methods and tools covered in the RBDM Guidelines recognizes that each RBDM application informs a specific set of decisions, and therefore, must be tailored to generate the proper scope of information.

3.5.1. Program Overview

The NMSRA is a biennial, broad horizontal assessment that produces three main products: a residual risk profile, a USCG risk reduction profile, and key observations. The residual risk profile estimates the expected societal loss that remains after the USCG has performed all of its prevention and response activities. The USCG risk reduction profile estimates the amount of risk that is avoided due to the USCG's response activities. Finally, the NMSRA offers key observations, including risk drivers and risk management opportunities.

These products were designed to inform a wide variety of USCG resource allocation decisions, both within and across missions, following the Planning, Programming, Budgeting and Execution process, including:

- Program Performance Plans
- Standard Operational Planning Process
- Strategic Planning Direction
- Resource Apportionment
- Resource Proposal Development and Evaluation
- Commandant's Budget Intent
- Performance Target Setting
- Mission Analysis Reports

Every 2 years, the USCG Office of Performance Management and Assessment (CG-DCO-81) performs the NMSRA. The NMSRA uses available enterprise data, performance management data, SMEs, and other models to provide decision makers and planning analysts a comprehensive view of the expected risk environment for the next 5 years. The NMSRA employs an approach that measures the value of unwanted outcomes the USCG is charged to minimize using a common measuring stick: risk to the American public. The result is an "apples to apples" comparison of negative outcomes spanning the USCG's enduring roles of Maritime Safety, Security and Stewardship. Table 12 provides summary information about the program.

Table 12. USCG NMSRA: Program Attributes

Attribute	Description
Origin Date	**2004**
Analytical Complexity	**Moderate** – Structured analysis technique tailored to various missions
Program Maturity	**High –** There have been six NMSRAs performed since 2004 with each building in complexity and analytical scope
Frequency of Use	**Biannual**
Risk Management Support to Mission Scope	**Broad** – NMSRA informs strategic decisions spanning all 11 USCG missions
Key Context Factors	• **Industry Scale:** High – the USCG is responsible for thousands of commercial vessels and maritime facilities • **Political Factors:** Because the USCG's mission set is so broad, there are numerous political factors that affect their operations and regulatory philosophy • **Agency Maturity:** High – agency was founded in 1790
Government Level of Effort	**Medium** – Risk analysis is performed by government representatives
Point of Contact	**Mr. Chris Toms**, Christopher.Toms@uscg.mil
Key References	• USCG Risk Management Overview

Figure 24 provides an overview of the USCG NMSRA risk management program by identifying the key inputs to the analysis process, the models used, the outputs of the models, and the decisions informed by the analysis. Table 13 provides details about each element presented in the figure.

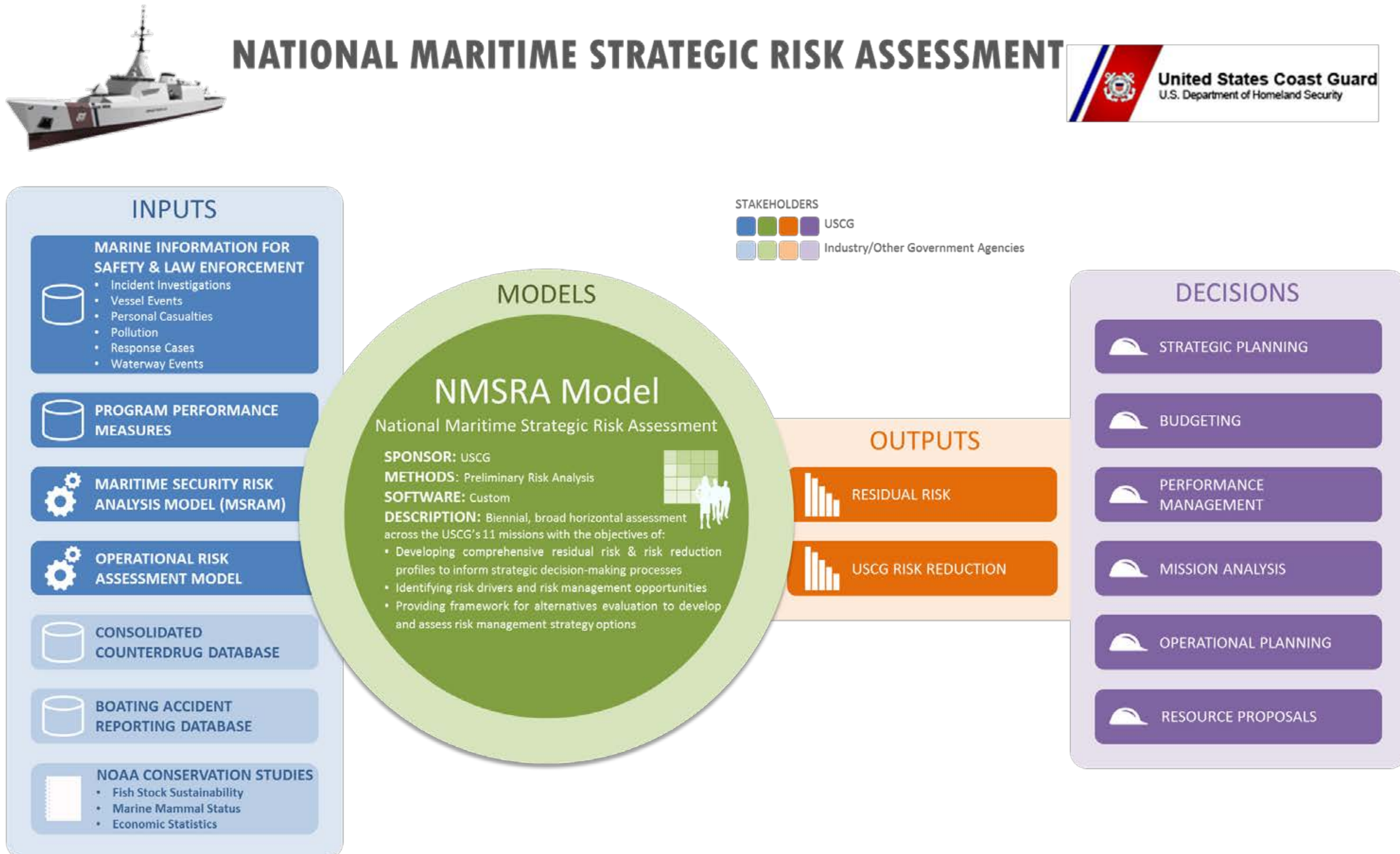


Figure 24. USG NMSRA: Program Overview

Table 13. USCG NMSRA: Program Details

USCG NMSRA: Program Details	
INPUTS	
Name	**Description**
Government	
Marine Information for Safety & Law Enforcement (MISLE)	**Type:** Database **Source:** USCG Incident Investigators **Description:** Maritime accident data are gathered by USCG incident investigators for reportable incidents. These incident reports gather detailed information on the accident, including: location, root cause information, types of vessels/facilities involved, fatalities, injuries, property damage, and spill size. • Incident Investigation: Describes location, consequences, root cause, etc. • Vessel Events: Identifies vessel types involved in the incident • Personal Casualties: Characterizes injuries and fatalities • Pollution: Describes spill characteristics (substance, amount, etc.) • Response Cases: Summarizes USCG Search and Rescue mission outcome (lives saved, lives lost, etc.) • Waterway Events: Describes major planned and unplanned waterway closures
Program Performance Measures	**Type:** Database **Source:** USCG Programs **Description:** Collection of USCG Government Performance Reporting Act (GPRA) measures explaining how well each of the USCG's programs is performing.
Maritime Security Risk Analysis Model (MSRAM)	**Type:** Model **Source:** USCG Analysts **Description:** USCG's model and supporting process deployed to USCG analysts in every major U.S. port to analyze the risk of assets within their area of responsibility to a variety of maritime terrorism attacks.
Operational Risk Assessment Model	**Type:** Model **Source:** USCG Analysts **Description:** Model that uses waterway-specific ice data and vessel traffic data to estimate the demand for ice breaking assets on each waterway for each week of the winter navigation season.
OGA	
Consolidated Counterdrug Database	**Type:** Database **Source:** Interagency Drug Enforcement Intelligence Analysts and Operators **Description:** Maritime drug smuggling data developed from interagency intelligence reports and drug seizure data provide estimates of noncommercial maritime U.S. bound cocaine flow and interagency removal rate (seizures).
Boating Accident Reporting Database (BARD)	**Type:** Database **Source:** State/Local Law Enforcement Agencies **Description:** Maritime accident data are gathered by state/local incident investigators for reportable incidents for recreational boating. These incident reports gather detailed information on the accident, including: location, fatalities, injuries, and property damage estimates.
National Oceanic and Atmospheric Administration (NOAA) Conservation Studies	**Type:** Reports **Source:** NOAA **Description:** A number of NOAA products are used to inform risk assessment • **Fish Stock Sustainability:** Measures the performance of U.S. fisheries through the Fish Stock Sustainability Index (FSSI). First implemented in 2005, the FSSI is a quarterly index that includes 227 fish stocks selected because of their importance to commercial and recreational fisheries.

USCG NMSRA: Program Details	
	• **Marine Mammal Status:** Provides an annual assessment of marine mammals. The report provides data about each mammal stock, including: stock status, geographic range, minimum population estimate, current population trends, productivity rates, biological removal levels, estimates of annual human-caused mortality and serious injury by source, and other factors. • **Economic Statistics:** Studies assessing economic impacts of invasive species damage.
MODELS	
Name	**Description**
Government	
NMSRA Model	NMSRA is broad horizontal assessment of risk across the USCG's 11 missions. • **Methods:** NMSRA is built on the *preliminary risk analysis* methodology, which is a simple, structured risk analysis process which guides SMEs through a systematic process where they make subjective judgments about the likelihood and consequences of a range of maritime scenarios. • **Software:** Custom Microsoft® Access® database solution automatically generates historical risk profiles, captures SME inputs during the risk analysis process, provides interactive results generation interface, and generates standard results reports.
Industry	
No industry models associated with this program.	
OUTPUTS	
Government	
Residual Risk	The risk (expected societal loss) that remains after the USCG has performed all of its prevention and response activities. Residual risk is expressed in units of Risk Index Number (RIN), defined as $1M of expected annual loss.
USCG Risk Reduction	Amount of loss to the American public that is expected to be mitigated by the USCG. With few exceptions, risk reduction is only measured for the USCG's response-oriented missions. Risk reduction is expressed in units of RIN.
Industry	
No industry outputs associated with this program.	
DECISIONS	
Name	**Description**
Government	
Strategic Planning	Used by strategic planners to (1) identify high risk areas to focus strategic planning efforts and (2) develop/evaluate potential strategic alternatives.
Budgeting	Used by the budget office to inform the budget build and evaluate the impacts of budget increments and decrements.
Performance Management	Used by the performance management office to establish performance targets within and across missions.
Mission Analysis	Used as part of the acquisition process to develop and evaluate various acquisition alternatives.
Operational Planning	Used by operational planners to (1) establish priorities within each mission, (2) allocate resource hours across all missions, and (3) distribute resource hours among geographic areas.
Resource Proposals	Used by the budget office to prioritize resource proposals for funding.
Industry	
No industry decisions informed by this program.	

The NMSRA program weighs the high-level risks and benefits for many different loss event scenarios within the USCG's diverse set of missions. It uses a moderately sized set of support data and sufficiently informs a variety of decisions (Figure 25). The NMSRA tool is updated biannually.

3.5.2. Conclusions

The USCG has several unique characteristics:

- Broad mission space – 11 missions
- Jurisdiction over a large variety of loss events
- Limited resources available for oversight
- Data collection involves identifying a comprehensive set of risk scenarios

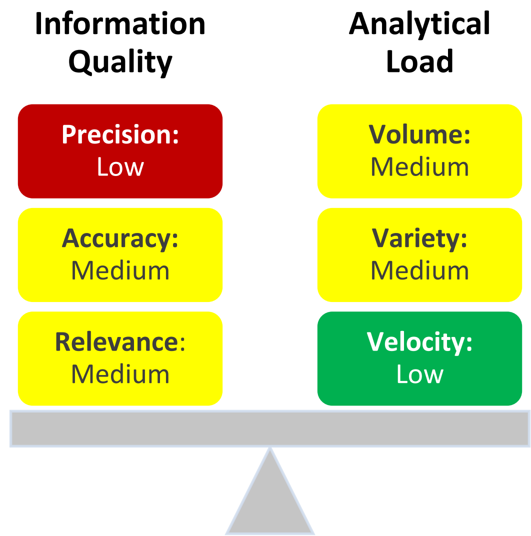


Figure 25. USCG NMSRA: Information Quality vs. Analytical Load

3.6. Summary

A review of Sections 3.1 through 3.5 illustrates that other government agencies have taken a wide range of approaches in developing their risk management programs. The design of the individual programs goes to various levels of detail, as the sponsors weigh their information requirements to understand future accident potential with the amount of analytical resources that could apply. Figure 26 summarizes the approaches for each of the agencies (except for HSE's approach, which is performed by industry).

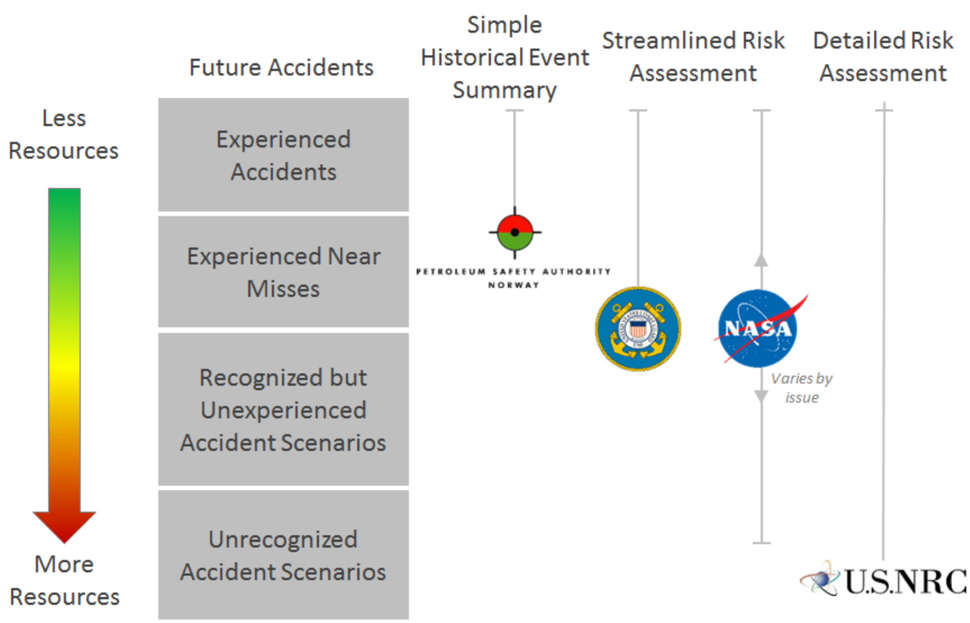


Figure 26. Depth of Risk Assessment vs. Resources Required

4. Application to BSEE

This section explores a number of internal and external factors that should be considered in the design of an operational risk management program within BSEE.

4.1. Industry Scale

The size and diversity of the regulated community have a significant influence on the risk analysis and management techniques that can be employed. To understand how BSEE's regulated industry compares to other IRF countries, the evaluation team chose multiple variables to describe facets of industry scale (Table 14), including: regulated facility count, worker hours, and barrel of oil equivalent (BOE) production.

Table 14. Measures of Industry Scale

Agency	Country	Industry Scale Measures*				
		Facilities	Worker Hours (millions)	Oil Production (millions of barrels)[11]	Gas Production (millions of BOE)	Total Production (millions of BOE)
NOPSEMA	Australia	151	15.7	189	304	493
ANP	Brazil	239	81.6	665	164	829
N-NLOSPB	Canada	9.8	3.9	84	35	119
DEA	Denmark	27	5.5	74	36	110
CNH	Mexico	710	197.9	693	1334	2027
SSM	Netherlands	171	9.1	21	100	121
WorkSafe NZ	New Zealand	7	1.7	18	17	35
PSA	Norway	98	45.4	657	698	1355
HSE	UK	321	62.8	266	250	516
BSEE	**USA**	**2894**	**122.7**	**472**	**273**	**745**

*2012 values

Figure 27 illustrates these values graphically where (1) the horizontal axis is the number of offshore facilities, (2) the vertical axis is offshore worker hours, and (3) the sizes of the circles are relative production volumes, in BOE. *Note: Denmark, New Zealand, and the Netherlands, which are smaller producers, have been removed from this graph to improve readability.*

[11] Gas production Barrels of Oil Equivalent (BOE) production levels provided by IRF study. Other data sources are listed in the spreadsheet workbook accompanying this report.

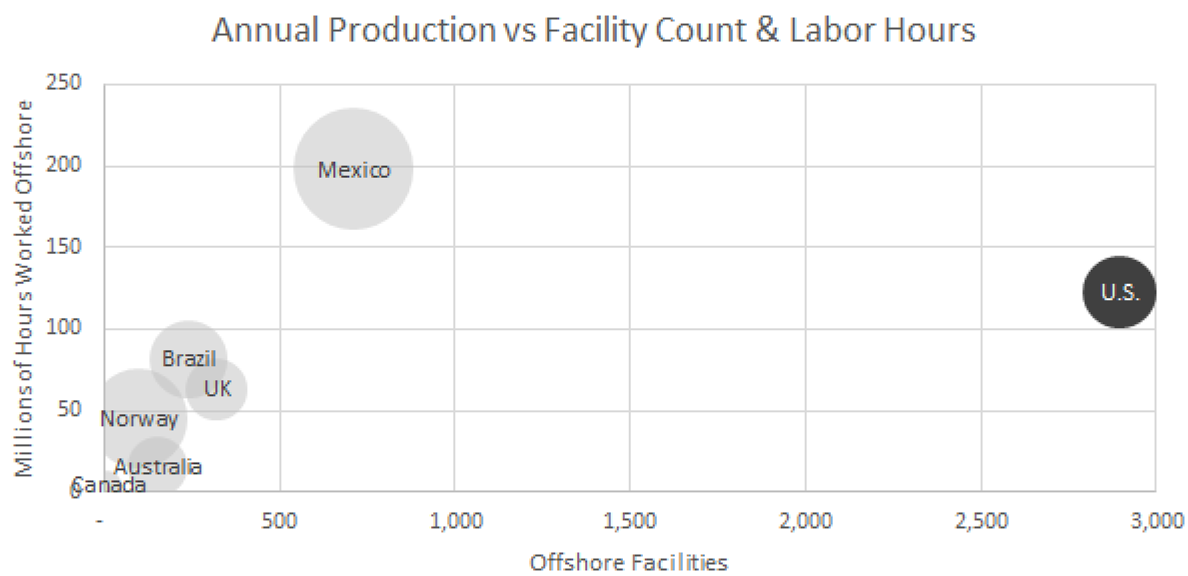


Figure 27. Annual Production vs. Offshore Facility Count and Labor Hours

This figure depicts the U.S. as an outlier in offshore production. While total production volume (the size of the bubble) is comparable to the UK, Brazil, and Norway, the U.S. has far more facilities, likely driven by the high number of small operations in the Gulf of Mexico's (GoM's) shallow waters. Also, notice that Mexico employs more offshore workers than the U.S., despite having far fewer facilities.

Figure 28 illustrates the U.S. as an outlier using a different metric: average production per facility.

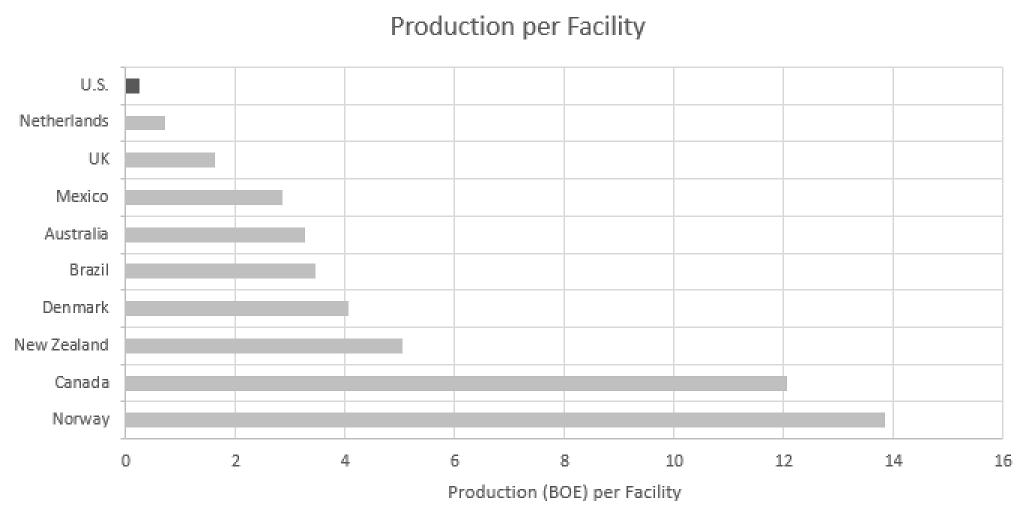


Figure 28. Average Production per Facility by Country

Facilities in Norway produce larger volumes and also process production from many subsea satellite wells. As more U.S. production moves into deeper waters, the average facility production is expected to increase.

Facilities under BSEE's jurisdiction produce much less, on average, than those in other IRF countries. The physical environment and historical context are drivers of this average facility production disparity. Because the GoM has a gradually sloping seabed away from the shore, there is a vast area of the OCS with shallow water, accessible by a large number of relatively small operators on low-cost platforms.[12] By contrast, in Denmark, Norway, and the UK, most production takes place in the North Sea's deep water wells. Operating in this environment requires advanced technology and taps into larger oil reservoirs, enabling larger production volumes for each facility.

As new production in the GoM continues to move to deeper water, shallow-water platforms will reach the end of their life and will be decommissioned, causing the total number of platforms in the GoM to decrease,[13] presumably bringing the GoM production per platform level closer to those of other countries.

Regardless of the factors driving the scale of industry operations, BSEE currently faces a unique regulatory challenge in overseeing a large number of facilities. Given that most regulatory, inspection, and data collection activities occur on a per facility basis, any regulatory approach, risk analysis and management program will necessarily be constrained by the requirement to operate on a large scale.

Practically, this constraint may explain, in part, why BSEE has continued to maintain a prescriptive regulatory regime. When BSEE inspects a platform, the inspector must review the standard set of Potential Incidents of Non-Compliance (PINCs) rather than evaluate each platform against its unique Safety Case. The same holds for the performance-based methodology applied by the NRC. To perform an NRC-level of analysis and oversight for all of the platforms under BSEE jurisdiction, BSEE would require more than 100 times as many resources to address the thousands of facilities and wide array of loss events.

4.2. Political Factors

Following the Macondo disaster, public concern about safe and clean OCS oil and gas operations was at an all-time high. In his comments regarding the disaster, the president denounced the MMS with the following statement:

> *"Oil companies showered regulators with gifts and favors, and were essentially allowed to conduct their own safety inspections and write their own regulations."*[14]

The president commissioned an investigation of the disaster, which recommended that the "Department of the Interior should develop a proactive, risk-based performance approach specific to individual facilities, operations and environments, similar to the Safety Case."

Since that time, the offshore regulatory agency has undergone reorganization, giving authority over safety and environmental functions to BSEE, while its sister agency, BOEM, holds responsibility over mapping and studying reservoirs, leasing offshore blocks, and collecting royalties.

[12] http://data.boem.gov/homepg/data_center/other/espis/espismaster.asp?appid=1
[13] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.196.2745&rep=rep1&type=pdf
[14] https://www.whitehouse.gov/the-press-office/remarks-president-nation-bp-oil-spill

BSEE has made other reforms. Recommendations to pursue performance-based regulation have been answered through the development of the Safety and Environmental Management Systems (SEMS) and SEMS II rules. Under the new rule, SEMS and its implementation are periodically reviewed by third-party auditors. This provides a hybrid prescriptive and performance-based approach.

Public attention seems to have moved on, but debate in politics and in academia over applicability of a Safety Case approach in American remains. One vocal advocate of Safety Cases is the Chairperson of the Chemical Safety Board (CSB), Rafael Moure-Eraso. In discussions of the many worker safety issues that the CSB addresses, the chairman clearly expressed his optimism about the approach.[15] The CSB's report on the findings of the Macondo disaster include contrasting the MMS regulatory regime to Safety Case and ALARP approaches.[16] The CSB's web site has pages devoted to facilitating discussion, primarily in support of the Safety Case approach.[17]

Many others oppose change in U.S. regulatory philosophy toward a Safety Case approach. CSB leadership appears to be divided on the issue[18] and many in American legal and safety have argued against the Safety Case approach. In Boston College Environmental Affairs Law Review Volume 38, Rena Steinzor argues against the application of Safety Case methodology in America for the following reasons:

- The ALARP fatality threshold is too low by American standards
- Industry does not want Safety Cases to be public and the public will not tolerate secrecy
- If British Safety Cases engender safety culture, why didn't it work for BP?

The paper also discusses the immense regulatory load of comprehending the contents of an individual Safety Case for each facility, when the documents often contain more than 500 pages of technical reporting.

In her "White Paper on the Use of Safety Cases in Certification and Regulation," Nancy Leveson, Professor of Aeronautics and Astronautics & Engineering Systems at MIT, discusses the perceived ethical dilemmas when performing cost/benefit analyses that involve the loss of life, such as used by ALARP methodology. She refers to the court precedent involving the poor design of the Ford Pinto automobile, which had fatal flaws but was justified by management on the grounds of cost/benefit analysis. In her words: "British regulations allow Safety Cases to be no more protective than preventing one in 1,000 worker deaths and requiring operators to spend no more than $1.5 million per life saved."

Discussions of Safety Cases often conclude that industry is opposed to the strategy. Some unions in other industries, such as United Steelworkers, have also been vocally opposed to Safety Cases. Moure-Eraso attributes some of this opposition purely to political agenda-pushing, as unions seek to crowd out other agencies claiming to represent labor.[19]

---

[15] http://www.csb.gov/testimony-of-rafael-moure-eraso-phd-chairperson-us-chemical-safety-board-before-the-us-senate-committee-on-environment-and-public-works-june-27-2013/
[16] http://www.csb.gov/assets/1/7/20140605_Macondo_Vol2_(0605v1).pdf
[17] http://www.csb.gov/working-papers-on-the-safety-case-regulatory-model-and-its-attributes/
[18] http://www.contracostatimes.com/contra-costa-times/ci_24922079/richmond-federal-board-at-odds-over-recommendations-stemming
[19] http://www.corporatecrimereporter.com/news/200/rafael-moure-eraso-tony-mazzochi-and-the-battle-for-worker-safety/

In the U.S., offshore oil workers are rarely organized into unions.[20] And regardless of the debate on Safety Case, a lack of strong union participation is a key political feature of the U.S. offshore regulatory environment. Without strong union participation, the Tripartite Collaboration that occurs in Norway and in other IRF countries such as Australia is not feasible. Figure 29 provides the evaluation team's assessment of how BSEE maintains a prescriptive regulatory regime with little collaboration with unions, unlike many other IRF countries.

Figure 29. Regulatory Approach and Tripartite Collaboration for IRF Countries

BSEE's political operating environment is also shaped by the jurisdiction of other regulators offshore. For example: the USCG has regulatory authority over certain elements of offshore platforms related to maritime safety. Over the years, the USCG has worked closed with BSEE to share inspection responsibilities to ensure compliance with both agencies' regulations while minimizing government inspection efforts. Beginning in 2002, BSEE (then MMS) was authorized to conduct inspections of USCG-regulated elements of platforms as part of BSEE's larger inspection scope. Under this agreement, the USCG retains regulatory authority over its self-inspection program and will continue to be responsible for initial facility inspections to ensure full compliance with all safety requirements under USCG jurisdiction. However, once the initial inspection has been completed by the USCG inspectors, the annual oversight inspections of the USCG-regulated items are conducted by BSEE inspectors on the behalf of the USCG.[21]

The USCG, as a regulator, is responsible for maritime safety; and therefore, operates in a very similar political environment to BSEE. While their regulated community tends to have a higher frequency of lower consequence events when compared to BSEE, there is still significant public concern about maritime accidents, such as the Exxon *Valdez*, that result in large oil spill accidents.

[20] http://www.eenews.net/stories/1059948147
[21] http://www.bsee.gov/Inspection-and-Enforcement/Inspection-Programs/Fixed-Platform-Self-Inspection-Program-Oversight/

In summary, the discussion surrounding Safety Case is politically charged, and BSEE is not pursuing a wholesale change in regulatory philosophy to Safety Case. The experience and comfort-level with such a regime is not present in the U.S. Unions currently have limited impact on regulation, providing little material for the construction of a regulatory system with strong Tripartite Collaboration. Finally, the presence of multiple regulators offshore makes it especially important that future regulations not be overbearing or redundant.

4.3. Agency Maturity

BSEE was created after the Macondo accident out of a reorganization of MMS. Currently, BSEE uses legacy inherited systems and data collection processes that may be disjointed or inefficient for supporting an operational risk management programs for regulations and inspections.

Although BSEE was created in 2011, much of the organizational knowledge and experience of its predecessors are still present. Many of the SMEs needed to make decisions and guide oversight remain. Therefore, despite the restructuring, BSEE has a head start in what is referred to as “agency maturity” in Section 3.

BSEE prescriptive regulatory program also has elements of maturity – the approach is well-understood by both industry and government. However, this regime came under fire following the Macondo accident. Since then, BSEE has increased inspections, enforcement activity, and effort on refining and improving its understanding of key risks. This report addresses remaining areas where BSEE can mature related to data collection and risk modeling. The evaluation team has identified the following program weaknesses:

- No centralized risk management function
- Inadequate risk lexicon
- Existing data collection has limited utility to support risk analysis and management efforts

BSEE currently performs a number of risk management functions. Incident reporting keeps BSEE aware of the incidents and accidents offshore. The BSEE *Risk-based Inspection Prioritization* project provides a means for targeted utilization of inspection resources, and the development of regulations are informed through an implicit understanding of risk. While each of these processes involve risk management, they are currently conducted in a largely independent and ad hoc manner, where data analysis techniques are not consistently applied and lessons are not shared among the processes (Figure 30).

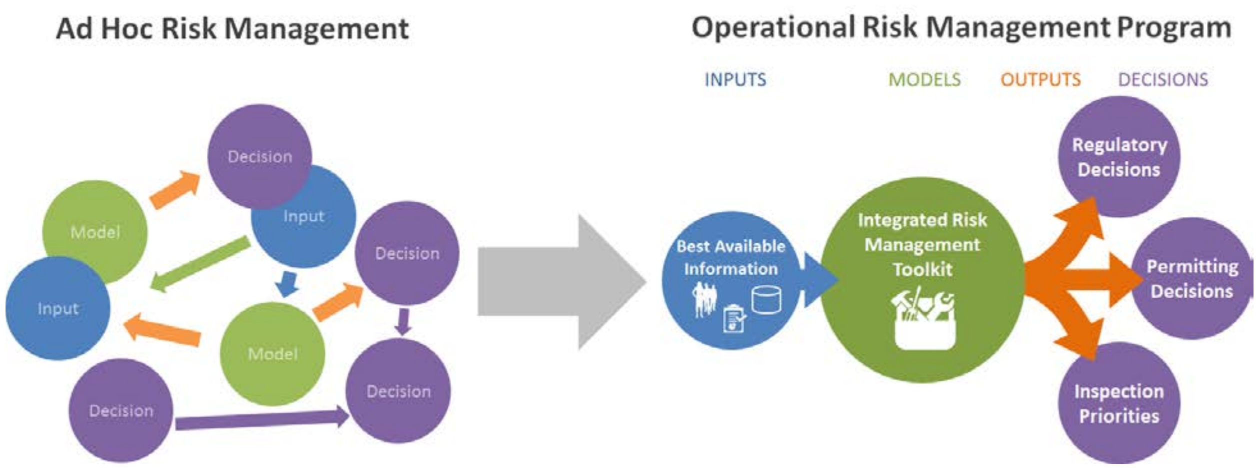


Figure 30. Ad Hoc vs. Centralized Risk Management

One result of the historical ad hoc approach is that BSEE does not have a standard lexicon or framework for understanding and communicating risk, either internally among its various operational functions, or with external stakeholders. BSEEs first annual report, issued earlier this year is a good step toward resolving this issue.

BSEE's data collection processes support current operations, but may not be extensible to support broader risk understanding. Some weaknesses in data collection are in the process of being addressed. As an example, BSEE is launching the SafeOCS program[22] in partnership with the Bureau of Transportation Statistics (BTS) to collect and analyze near miss data. As the evaluation team reviewed the data currently available to BSEE, issues of data quality related to classifying and describing incidents, accidents, and risk are most prevalent. In most cases, the most risk-relevant information is contained in free-text fields that are extremely difficult to use for statistical analyses. Appendix 0 compares key performance indicators that BSEE generates and uses to those of other offshore oil and gas regulators, specifically: HSE, PSA, and NOPSEMA.

BSEE has only recently begun enforcing its performance-based SEMS program. The lack of high confidence performance indicators makes assessing the effectiveness of such a program (or any regulatory framework) especially difficult.

4.4. Lessons Learned

The wholesale adoption of one of the agency programs documented in Section 3 is not likely to succeed for BSEE. Its operating environment of extreme industry scale, weak unions, political implications, and underdeveloped risk management infrastructure all set BSEE apart from any other regulator, foreign or domestic. In comparing any two regulators, there will always be differences requiring tailored approaches, including differences in mission set, hazards, operating environments, organizational

[22] http://www.bsee.gov/BSEE-Newsroom/Press-Releases/2015/BSEE-Director-Brian-Salerno-Announces-Key-Efforts-to-Reduce-Risk-Offshore/

cultures, and understanding of risk. BSEE has a number of unique challenges in systematically analyzing and managing risk:

- **Dynamic Industry -** Regulated industry is continuing to apply new technologies and migrate into more extreme operating environments (e.g., deep water, high pressure, Arctic)
- **Rare, Catastrophic Risks** - Risk for many scenarios are dominated by rare, catastrophic events, making historical incident analysis of limited utility for predicting future risks
- **Highly Complex Systems** - OCS oil and gas exploration and production operations are highly complex systems relying on a mix of engineered safeguards and human actions
- **Multiple scenarios of concern –** BSEE seeks to prevent a broad array of safety and environmental accidents, including: fires, explosions, blowouts, dropped objects, etc.

While their issues may vary, lessons can still be learned from other agencies that can be useful in developing a successful program for BSEE. The evaluation team has identified the following attributes about select risk management programs that could be emulated by BSEE (Table 15).

Table 15. Key Attributes of Select Other Agency Risk Management Programs

Agency	Key Attributes
PSA	*RNNP* is valuable for establishing annual priorities and communicating with industry
USCG	*NMSRA* program provides a high-level understanding of risk across their mission set that is applied to strategic decisions
NASA	*APA* program is a model for screening risks, identifying precursors, developing a risk inventory, and cutting across operational silos.
NRC	*Risk-Informed Regulations and Inspections Program* demonstrates the gold standard of comprehensive risk management programs
HSE	*Safety Case* represents an alternative to government-led risk management that puts the onus on industry to design and demonstrate that its operations are within society's risk tolerance thresholds

Some of these lessons come with important caveats. The HSE Safety Case and NRC approaches would likely require significant modification to be feasible for BSEE because BSEE's industry scale is so much larger. On top of these issues of scale, political division over the use of Safety Case may keep such a methodology from ever gaining traction, especially if SEMS seems to be an effective performance-based alternative.

5. Potential Risk Methodologies for BSEE Applications

Section 2 provides an overview of key risk management concepts and introduces that that there are many different approaches to risk analysis and management. The key in designing an effective risk management process or program is to ensure that it generates information that is useful to decision makers given the available analytical resources. Section 3 builds on this theory by providing numerous real world examples of risk management programs within other U.S. and international agencies. This collection of risk management programs represents an array of implementation options from simple methodologies with a narrow focus to all-inclusive risk management programs employing highly sophisticated modeling techniques. Section 0 explores a number of internal and external factors that should be considered in the design of an operational risk management program within BSEE.

This section builds upon that background information by presenting a concept for a comprehensive operational risk management program within BSEE OORP and identifying the risk methodologies that are best suited to generate useful information for key decisions given an understanding of current constraints, including: available enterprise data, access to BSEE and industry SMEs, and analytical resources.

5.1. Vision of an Operational Risk Management Program

An operational risk management program, when fully mature, would enable BSEE to proactively identify, communicate, and manage risks related to incidents that may result in unwanted safety and environmental consequences. As illustrated in Figure 31, the risk management program would apply existing enterprise data, using a variety of aligned risk management tools to generate risk information to support decisions related to regulations, permitting, and inspections.

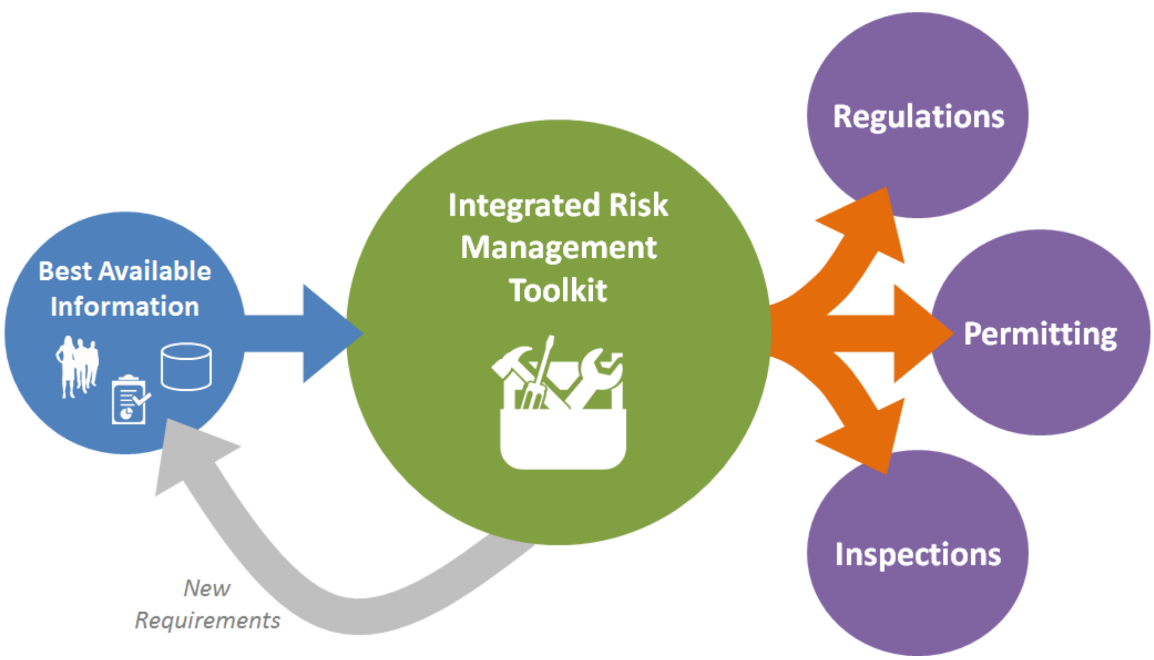


Figure 31. Risk Management Program Concept

Key characteristics of a fully mature operational risk management program, include:

- ✓ Providing a centralized risk management function that ensures that methodologies are aligned with one another and compliant with best practices
- ✓ Facilitating all phases of the risk management cycle (Figure 1)
- ✓ Providing a core risk management team with detailed risk modeling expertise capable of tapping into niche technical expertise throughout the organization to facilitate risk analysis and management activities
- ✓ Training personnel to ensure staff has the required competencies to support the program
- ✓ Implementing and maintaining the appropriate risk management tools required by the program
- ✓ Making use of the best available information: BSEE data, expert opinion, engineering studies, design documents, as well as 3rd party data
- ✓ Identifying enterprise data requirements to address data gaps and improve data quality
- ✓ Optimizing analytical effort spent on an issue based on the issue's assessed risk and certainty in that assessment (e.g., more effort studying high risk and high uncertainty issues)
- ✓ Generating outputs with sufficient accuracy, precision, and relevance to support key regulations, permitting, and inspections-related decisions
- ✓ Intuitively communicating risk information by leveraging cutting edge data visualization techniques and tools

A program with these characteristics would be capable of providing valuable insight to support a wide variety of decisions. Table 16 illustrates the types of decision support a well-designed and mature risk management program could deliver.

Table 16. Decision Support Examples

Regulatory-related Decision Support
• Strategic understanding of high risk factors (platform type, mode, region, incident type, etc.) • Development of new regulations • Prioritization of modes of operation • Cost/benefit estimates to support regulatory analysis of proposed rules • Prioritization of systems and components • Understanding of the effectiveness of existing regulations • Understanding of the risk by region (Atlantic, Pacific, and GoM) • Prioritization of platforms, platform types, reservoir types, and geographies • Understanding of the effectiveness of individual elements within existing regulations • Understanding of the unique risks to various physical environments
Inspection-related Decision Support
• Focusing inspection activities: platforms, systems, components, PINCs • Understanding effectiveness of inspections • Understanding effectiveness of inspection elements (e.g., PINCs) • Understanding cost/benefit of inspections • Prioritizing inspection findings
SEMS-related Decision Support
• Understanding effectiveness of SEMS program • Understanding effectiveness of individual elements within SEMS • Understanding effectiveness of audits in identifying management system failures • Understanding sensitivity of platform risk to audit performance

5.2. Potential Methods for BSEE

Achieving a future comprehensive system requires deliberate planning and integration of sound risk methodologies, alignment throughout the organization, and well-planned implementation. This section describes the foundation of a comprehensive system based on an understanding of the vision for the future state. It is essential to understand that the requirements of the system will evolve over time based on a number of influencing factors, such as:

- Changing leadership priorities for the organization
- Altering regulatory philosophy, such as migrating to a Safety Case approach
- Shifting political landscape or changing societal acceptance of offshore oil and gas risks
- Supporting new decision-making processes with risk information (e.g., additions or revisions to those described in Table 16)
- Improving breadth and quality of available internal and external data
- Increasing computing power and modeling capabilities enabling employment of new risk modeling techniques (e.g., complex system simulations)

For this fluid environment, the evaluation team proposes a collection of widely-regarded risk methods to serve as toolkit from which BSEE can generate tailored risk information to support decisions while assuring alignment across the efforts. This sound foundation both addresses currently identified needs while providing the nimbleness to change courses to meet new challenges. This approach will support decisions in the near term while reserving the right to get smarter in the long term.

As introduced in Section 2.7 and discussed throughout this document, there are many implications and trade-offs between data quality and analytical load that must be considered when choosing a risk method. The key is to select a method that will generate risk information of sufficient accuracy, precision, and relevance to support the decision. Recognizing this, the evaluation team recommends multiple methods ranging from simple to complex that are capable of providing the decision support listed in Table 16, albeit to different levels of accuracy, precision, and relevance. These methods collectively represent a subset of those listed in Table 3. The options are not necessarily independent but can build off of each other to study issues to different levels of detail based on the assessed risk.

Similar to the other agency risk management program overviews, Figure 32 provides an overview of a mature operational risk management program by identifying the key inputs (current and future) to the analysis process, the models, the outputs of the models, and the decisions informed by the analysis. Table 17 provides details about each element presented in the figure.

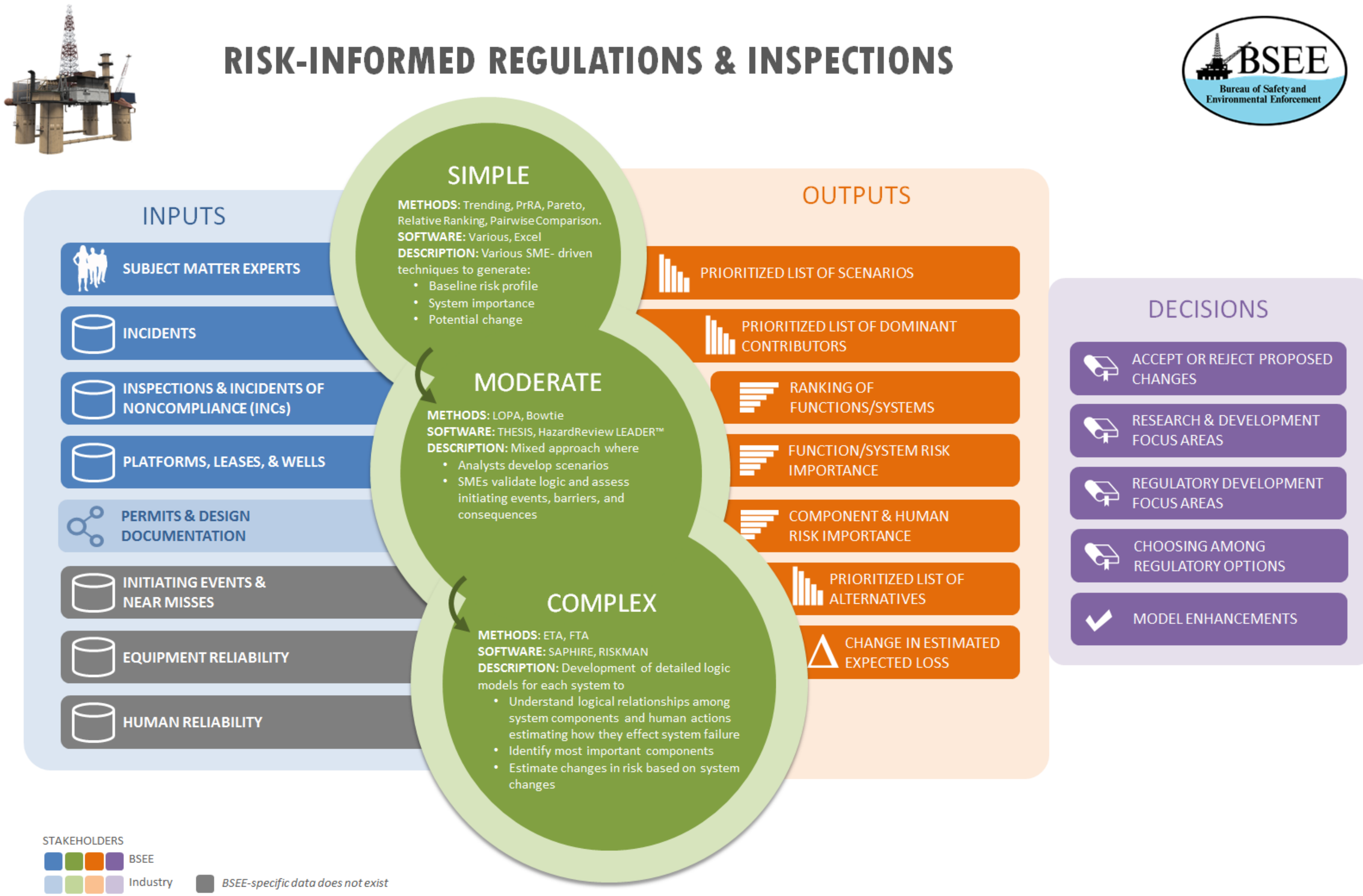


Figure 32. Potential BSEE Operational Risk Management Program Overview Diagram

Table 17. Potential BSEE Operational Risk Management: Program Details

Potential BSEE Operational Risk Management: Program Details	
INPUTS	
Name	**Description**
Government	
Subject Matter Experts	**Type:** SME Judgment **Source:** Experts in a variety of relevant disciplines **Description:** Regardless of the resolution of risk information required, SMEs perform a vital role in any risk program. At simple- to moderate-level models, SMEs provide much of the information needed to establish risk levels, evaluate the importance of systems, and estimate the risk reduction impact of proposed changes (e.g., new regulations). In moderate- to complex-level risk modeling, SME input is essential for developing logic, choosing the appropriate input data, and when necessary, filling data gaps.
Incidents	**Type:** TIMS Database **Source:** Incident Investigations **Description:** Incident data are the most essential input to risk modeling as they describe accidents that have happened in the past. This information is useful in developing scenario frameworks, understanding the range of potential consequences, estimating the likelihood of occurrence, and understanding what failures led to the event (e.g., human errors, equipment failures, management system failures). The incident table within TIMS has numerous data fields that can be leveraged to support simple, moderate, and complex risk methods. **Notable Fields:** • Incident Type Flags • Platform ID • Lease ID • Operator ID • Pollution Data • Root Cause Flags • Text Remark
Inspections	**Type:** Database **Source:** Inspection Reports **Description:** Inspection data are useful for understanding the outcomes of BSEE inspections. Theoretically, this data can be used to help inform equipment reliability estimates and the scope and effectiveness of inspection activities, but there are application challenges. **Notable Fields:** • Complex ID • Facility Type • Inspection Type • Inspection Date • Length of Inspection Time • Equipment Counts
Incidents of Noncompliance (INCs)	**Type:** Database **Source:** Inspection Findings **Description:** INC data are useful for providing insight into the level of industry compliance. Large fluctuations year-to-year in the number of INC findings over the last decade suggest that INC data may not be very useful for trend analysis. However, platform-to-platform comparisons may be still be possible. Theoretically, INC data could help SMEs understand current risk barrier quality. For example, higher numbers of INCs per platform could indicate lower barrier

	quality. **Risk Significant Fields:** • Complex ID • Facility Type • Rig Type • Enforcement • Violation Description (Text) • Equipment Name • Operation Type Code
Platforms & Leases	**Type:** Database **Source:** Industry Reporting/Permissioning **Description:** This data are most useful for developing scenarios and correlating platform and well characteristics to expected losses. Information about the type of platform and environmental conditions (e.g., water depth, well pressure, production volumes) will provide insights into dominant risk contributors and will potentially support estimations of consequence potential from major accidents. **Notable Fields:** • Various Platform Status Flags • Hours manned per day • Major Complex Flag • Heliport flag • Injection Code • Field Name • Crane Count • Bed Count • Lease Status • Lease Periods • Operators • Area/Block
Geological/Geophysical Conditions	**Type:** Database **Source:** BOEM **Description:** Readings of reservoir conditions from various wells. **Description:** This data are most useful for developing scenarios and correlating reservoir characteristics, such as temperature, pressure, and depth to expected losses. Information about the reservoir will provide insights into dominant risk contributors and will potentially support estimations of consequence potential from major accidents. **Notable Fields:** • Well Number • Field Name • Reservoir Area/Volume • Porosity • Permeability • Well Pressure • Well Temperature
Industry	
Permits & Design Documentation	**Type:** Reports **Source:** Industry Reporting/Permissioning **Description:** Documentation provided by industry related to the design and configuration of platforms and their safety systems is essential for being able to build the logic models required for moderate and complex analysis methods.

Not Yet Available BSEE Data	
Initiating Events & Near Misses	**Type:** Database **Source:** Industry Reporting **Description:** Near miss data are intended to allow regulators to understand how often events occur which, under other circumstances, could lead to an incident. These are useful in informing initiating event frequency estimates and understanding the effectiveness of barriers for moderate and complex modeling techniques. While these data are currently not collected, BSEE recently announced that, in partnership with the BTS, it was developing a confidential near-miss reporting system for use in the OCS. **Necessary Fields:** • Event Category • Date of Occurrence • Failure type (Equipment, Human, etc.) • Systems Involved • Equipment Involved • Components Involved • Response Mechanisms Involved • Estimated Magnitude of Worst Case Outcome **Alternate Data Sources:** WOAD provides information to inform initiating event frequency estimates.
Equipment Reliability	**Type:** Database **Source:** BSEE Data Collection/Studies **Description:** Industry uses reliability data as inputs for FMEA and FMECA analyses as well as reliability-centered maintenance (RCM) programs. Historically, these data have not been systematically collected by offshore regulators, including BSEE. However, detailed QRA modeling requires equipment reliability data as inputs. Good reliability data will meet the following specifications: • Intuitive and effective equipment and component taxonomy • Comprehensive categorization of causes of failure • Comprehensive categorization of failure outcome types and severities • Calendar time versus operational time consideration • Robust assumptions regarding equipment exposure and contribution to failures **Necessary Fields:** • System/Equipment/Component Type (Taxonomy Number) • Hours of calendar time prior to failure • Hours of operational time prior to failure • Failure Type (damage, wear and tear, improper use) • Failure Mode (Leaking, plugged, inoperable) • Failed Sub-System/Equipment/Component **Alternate Data Sources:** OREDA reliability data are an alternative to a BSEE-sponsored equipment reliability database. Although OREDA raw data are proprietary to select major oil producing companies that contribute to it, the program periodically produces an updated edition of the OREDA handbook. The handbook contains failure rates per million hours for a number of pieces of equipment both topside and subsea. Furthermore, for each equipment type, it includes summaries of percentages of failures attributable to various maintainable components, failure modes, and failure descriptions.
Human Reliability	**Type:** Database **Source:** BSEE Data Collection/Studies **Description:** Detailed analysis of component reliability within the context of a

<table>
<tr><td></td><td>system requires consideration of the human elements involved. The NRC's HFIS is an example of high-quality human reliability data collected by a regulator. HFIS aggregates information on worker training, procedures, fitness for duty, management and oversight, problem identification and resolution, communication, human-system interface and environment and other work practices.
Alternate Data Sources: NRC Human Failure Models</td></tr>
<tr><td colspan="2">MODELS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td>Simple Models</td><td>Objective: There are a number of simple techniques that can be applied to BSEE to generate risk results that convey: (1) the baseline <u>risk</u> profile, (2) the <u>importance</u> of various systems in reducing risk, and (3) the potential <u>change</u> in risk if alternate risk management strategies are employed. As described in Section 2.7, more resources are required to generate risk information with higher levels of certainty and precision. Simple methods will be almost entirely supported by structured elicitation of SMEs equipped with knowledge of readily available data to generate accurate, but low precision risk profiles. While coarse, these risk profiles can be very useful in establishing an understanding of risk, importance, and change. Often, simple models serve to screen out low risk issues from further modeling.
Methods: There are numerous simple risk modeling techniques, but the evaluation team believes the following are most appropriate for BSEE. The types of information that can be generated by each technique are documented in the parentheses. Finally, the risk management team would likely implement a combination of these methods as part of a holistic solution.
Trend Analysis – Compilation and analysis of data over a defined time period (e.g., 10 years) from incident reports, inspection findings, documentation submitted by industry, and lease information to identify current risk levels and historical risk trends.
PrRA – Structured SME elicitation to systematically review available risk-related data and apply SME judgment to establish relevant loss events, severity/likelihood risk profiles associated with these loss events, and the dominant contributors to each loss event. This method revolves around loss events (i.e., what can go wrong) and the scenarios in which they occur but does little to develop understanding of scenario sub-elements such as initiating events, layers of protection, and specific consequence types.
Secondary Models (Pareto Analysis, Relative Ranking, Pairwise Comparison) – Within the context of a PrRA SME workshop, secondary methods can be used to develop scenario-level risk importance and/or perform change analysis. Estimating the importance of systems in reducing risk of scenarios can be achieved through systematic elicitation of SMEs using these techniques.
Qualitative: Provide a list of dominant scenarios for each loss event type provided based on SME judgment
Quantitative: Provide a relative ranking of dominant contributors
SMEs can also estimate or rank various alternative risk management strategies based on their expected changes in risk.
Level of Effort: Multi-day workshops for each key area of assessment
Software: Various – can generally be implemented in Excel spreadsheets
Direct Model Output: The outputs that can be generated by the various methods</td></tr>
</table>

are described in the following matrix:

Outputs	Trend Analysis	PrRA	Pareto Analysis	Relative Ranking	Pairwise Comparison
Risk Outputs					
Incident Trends	✓				
Risk Ranked List of Scenarios		✓	✓	✓	✓
Importance Outputs					
Risk Ranked List of Dominant Contributors			✓	✓	
System Risk Importance			✓	✓	✓
Component/Human Action Risk Importance					
Change Outputs					
Prioritized List of Alternatives		✓		✓	✓
Change in Estimated Expected Loss		✓			

Moderate Models

Objective: The moderate models should be applied to select medium and high risk scenarios, as assessed by the simple techniques. These methods proceed to the next level of detail by developing the logical relationships between scenarios and the barriers that are designed to address them.

Methods: There are several moderately complex risk modeling techniques that could be employed, but the evaluation team believes that LOPA/Bowtie are well aligned to BSEE's need to generate more precise estimates of risk, system importance, and change. These models use a mixed approach that includes:

- Analysts developing scenarios by describing initiating events, potential consequences and mapping layers of protection (barriers)
- SMEs participating in workshops to validate/update scenario logic and assess initiating event likelihoods, barrier effectiveness, and consequence potential

Level of Effort: Weeks to months to develop all needed scenarios by individual SMEs and several day workshops for each key area of assessment.

Software: Various, including: THESIS and HazardReview LEADER™

Direct Model Output: The outputs that can be generated by the various methods are described in the following matrix:

Outputs	LOPA	Bowtie
Risk Outputs		
Incident Trends		
Risk Ranked List of Scenarios	✓	✓
Importance Outputs		
Risk Ranked List of Dominant Contributors	✓	✓
System Risk Importance	✓	✓
Component/Human Action Risk Importance		
Change Outputs		
Prioritized List of Alternatives	✓	✓
Change in Estimated Expected Loss		

Complex Models	**Objective:** The complex models should be applied to only select high risk scenarios where significant uncertainty remains, as assessed by the simple techniques. These methods proceed to the next level of detail by developing the logical relationships and dependencies among components and human actions within a system. **Methods:** ETA/FTA are ideal techniques to generate more objective and precise estimates of risk, system/component importance, and change at a very detailed level. This methods support development of detailed logic models for (1) the identification of potential loss scenarios using the ETA and (2) the identification of the specific function, system, component, and human failures that can lead to the initiating event and/or the loss of each layer of protection using FTA. Similar to the moderate LOPA/Bowtie approach, ETA/FTA require building of scenarios leading to loss events and the associated consequences. In addition, the FTAs provide detailed development of the logic for how the initiating event occurs and how each layer of protection failure could occur. This allows for the development of the logic models down to the component/human action level if needed and to the level of available failure rate data. In addition, the detailed logic diagrams can support more explicit dependent failure event assessments to explicitly identify potential common cause failures between multiple layers of protection. Finally, these models support the identification of the detailed failure paths for each sequence. These detailed failure paths can be used to quantitatively establish the importance of systems, components, and or human actions. The importance results can include both (1) contribution to BSEE mission risk and (2) sensitivity of BSEE mission risk to changes in their effectiveness. **Level of Effort:** Months to develop detailed system logic and gather appropriate failure data for each key area of assessment. **Software:** SAPHIRE, RISKMAN **Direct Model Output:** The outputs that can be generated by the various methods are described in the following matrix:

Outputs	ETA/FTA
Risk Outputs	
Incident Trends	
Risk Ranked List of Scenarios	✓
Importance Outputs	
Risk Ranked List of Dominant Contributors	✓
System Risk Importance	✓
Component/Human Action Risk Importance	✓
Change Outputs	
Prioritized List of Alternatives	✓
Change in Estimated Expected Loss	✓

OUTPUTS	
Name	**Description**
Government	
Incident Trends	**Type:** Trends **Description:** Presentation of the risk factors, such as incident rates, over time. Trend analysis can be very useful for organizations with profiles driven by high frequency, low consequence incidents. For example, insurance companies heavily leverage trend analysis to inform setting of insurance rates. For organizations, such as BSEE, which has a risk profile with significant contribution from low

frequency, high consequence events, trend analysis solely on incidents has less utility. That being said, trend analysis on other risk-related factors can be very useful to inform risk analysis. Trend analysis on incidents, near misses, INCs, drilling and production operations are useful in providing context to SMEs in how the operating environment is changing.

Simple: Trend analysis results are generally only useful at a high-level, limiting their direct application to simple models. Trend analysis outputs should be applied to support other methods, such as PrRA.

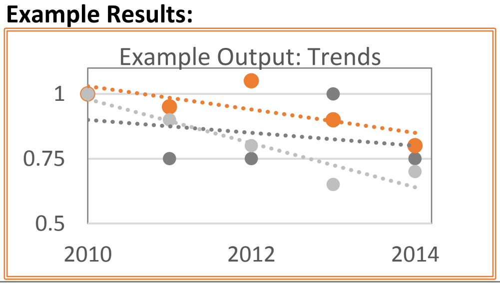
Method Quality Summary:

Output Quality Factors	Simple	Moderate	Complex
	Trend Analysis	N/A	N/A
Objectivity	High		
Precision	Low		
Confidence	Low		

Decisions Informed:

- Informing Stakeholders

Example Results:



Risk Ranked List of Scenarios

Type: Ranked List

Description: The risk ranked list of scenarios has two major components: a scenario structure and an assessed risk level. The scenario structure indicates the high-level dimensions that can be used to measure and categorize the spectrum of risk exposure. Dimensions that define a scenario could include, but are not limited to:

- Operating Modes (e.g., exploration, production, and workover)
- Operational configurations (e.g., platform type)
- Incident Types (fires, personnel mishaps)

The assessed risk level is a function of its likelihood and consequence. Risk levels will vary in objectivity, confidence, and precision based on the different models used to develop the estimates.

Simple: Trend analysis and PrRA can provide high level scenario risk ranking. Trend analysis provides relatively objective data and SMEs involved in the PrRA process review relevant object data and apply their knowledge and expertise to assign risk likelihood and severity categories to each scenario. Even though trend analysis and PrRA processes produce relatively low confidence risk information, they ideally identify, with sufficient confidence, low risk scenarios that do not require further analysis.

Moderate: When the simple model identifies high-risk scenarios that are not sufficiently well understood, a LOPA or Bowtie model will produce results on a system/barrier level of detail. This level of detail provides higher confidence

	estimates of scenarios risk. ***Complex:*** Complex methods such as ETA/FTA, which model scenarios and systems at a very detailed level are capable of generating accurate and precise scenario risk rankings. **Method Quality Summary:** The following table summarizes the quality of the output for the various simple, moderate, and complex methods.

Output Quality Factors	Simple		Moderate	Complex
	Trend Analysis	PrRA	LOPA/Bowtie	ETA/FTA
Objectivity	High	Low	Low	Medium/High
Precision	Low	Low/Medium	Low/Medium	Medium/High
Confidence	Low/Medium	Medium	Medium	Medium/High

Decisions Informed:

- Select Strategic Initiatives
- Inform Stakeholders

Example Results:

Scenarios				Risk Level	Risk Index Number
Rank	Mode	Platform Type	Incident		
1	Drilling	Floating	Fire-Explosion	Very High	1,200
2	Drilling	Floating	Blowout	Very High	1,000
3	Production	Fixed	Fire-Explosion	High	550
100	Drilling	Fixed	Personnel Mishap	Very Low	0.1

Risk Ranked List of Dominant Contributors	**Type:** Ranked List **Description:** Dominant contributors are patterns in the risk profile which point to specific factors that strongly correlated with risk. Key dominant contributors, if not well understood, warrant detailed study. ***Simple:*** The simple model will identify dominant contributors at the scenario level. Ideally, the dominant contributors will be identifiable along dimensions of the scenario structure. An example of a scenario-level dominant contributor might be high production capacity of a platform if it had been observed that high production capacity platforms have dramatically higher incident rates. The PrRA process may also identify system- or even component-level issues that SMEs believe are dominant contributors. ***Moderate:*** The moderate methods, which model the relationships between layers of protection and scenarios, can methodically identify system failures that contribute significantly to scenario risk. ***Complex:*** Since the complex methods perform analysis at the component level, they can identify component, human, and common cause failures that contribute significantly to scenario risk. **Method Quality Summary:** The following table summarizes the quality of the output for the various simple, moderate, and complex methods.

Output Quality Factors	Simple		Moderate	Complex
	Trend Analysis	PrRA	LOPA/Bowtie	ETA/FTA
Objectivity	High	Low	Low	Medium/High
Precision	Low	Low	Low/Medium	Medium/High
Confidence	Low	Low/Medium	Medium	Medium/High

Decisions Informed:

- Select Strategic Initiatives
- Inspection Prioritization
- Model Enhancements

Example Results:

Mode	*Drilling*	*Drilling*	*Production*
Platform Type	*Floating*	*Floating*	*Fixed*
Incident	*Fire-Explosion*	*Blowout*	*Fire-Explosion*
Ranking	**Dominant Contributors**		
1	Human Factors	Human Factors	Welding Operations
2	Welding Operations	Loss of Position	Gas Leaks

System Risk Importance Metrics

Type: Importance

Description: Risk importance metrics evaluate a system's importance in maintaining and further reducing the risk to the operation. There are a variety of risk measures that are useful for (1) prioritizing which systems are most important for assuring reliability and (2) prioritizing potential system performance improvements which can most reduce the risk.

Simple: The application of simple, structured methods (e.g., Pareto, risk indexing, pairwise) for eliciting SME opinion can be applied to generate coarse understanding of system importance.

Moderate: LOPA/Bowtie methods can provide risk sensitivity metrics for barriers against loss events.

Complex: Within a formal ETA/FTA model, there are three types of importance metrics that can be generated at the system level:

- **Structural importance** represents a count of the number of unique ways a failure of the system can lead to major loss event
- **Risk sensitivity** is the likelihood of a loss event occurring given the failure of that system/component
- **Risk contribution** is the likelihood that failure of a particular system is involved, given that a loss event has occurred

Method Quality Summary: The following table summarizes the quality of the output for the various simple, moderate, and complex methods.

Output Quality Factors	**Simple**		**Moderate**	**Complex**
	Pairwise	Pareto, Risk Index	LOPA/Bowtie	ETA/FTA
Objectivity	Low	Low	Low/Medium	High
Precision	Low	Low	Low/Medium	High
Confidence	Low	Low	Low/Medium	High

Decisions Informed:

- Select Strategic Initiatives
- Regulation Prioritization
- Inspection Prioritization

Example Qualitative Results:

System	Contribution	Sensitivity
Emergency Power	High	Medium
Fire & Gas Detection	Low	Medium
Position Keeping	High	High

Example Quantitative Results:

<table>
<tr><td></td><td>

System	Sensitivity (Risk Points*)
Emergency Power	25
Fire & Gas Detection	45
Position Keeping	200

*Definition of risk points must be developed and could be established on a relative or absolute basis
</td></tr>
<tr><td>Component/Human Action Risk Importance Metrics</td><td>

Type: Importance
Description: Component and Human Action importance metrics also include structural importance, risk sensitivity, and risk contribution. Structural importance can be determined from a logic model while risk sensitivity and contribution require detailed reliability data and human action data in order to be calculated.
Complex: These metrics are only available through the use of a complex method.
Method Quality Summary: The following table summarizes the quality of the output for the various simple, moderate, and complex methods.

Output Quality Factors	Simple *N/A*	Moderate *N/A*	Complex *ETA/FTA*
Objectivity			High
Precision			High
Confidence			High

Decisions Informed:

- Select Strategic Initiatives
- Regulation Prioritization
- Inspection Prioritization

Example Results:

Component/Human Action	Sensitivity (Risk Points)
Timely ESD Activation	17.5
Smoke Detector	6.2
Generator Fuel Line	0.013
</td></tr>
<tr><td>Prioritized List of Alternatives</td><td>

Type: Ranked List
Description: Prioritized list of alternatives provide an assessment of the expected risk reduction impact of developed risk management strategies, such as new rules within a regulation, updated inspection protocols, etc.
Simple: The application of simple, structured methods (e.g., Pareto, pairwise) for eliciting SME opinion on the expected risk reduction for various alternatives. Depending on how the elicitation is structured, the results can take several forms, including, but not limited to:

- Ranked lists
- Categorized impact (e.g., high, medium, low)
- Relative ranking of alternatives (order of magnitude)

Method Quality Summary: The following table summarizes the quality of the output for the various simple, moderate, and complex methods.

Output Quality Factors	Simple		Moderate	Complex
	Pairwise	Risk Index	N/A	N/A
Objectivity	Low	Low		
Precision	Low	Low		
Confidence	Low	Low		

Decisions Informed:

- Regulation Prioritization

Example Results: The following table summarizes the quality of the output for
</td></tr>
</table>

<table>
<tr><td></td><td>the various simple, moderate, and complex methods.
<table><tr><th>Proposed Measure</th><th>Impact to Risk Level</th></tr>
<tr><td>Alternative A</td><td>High</td></tr>
<tr><td>Alternative B</td><td>Medium</td></tr>
<tr><td>Alternative C</td><td>Low</td></tr></table></td></tr>
<tr><td>Change in Estimated Expected Loss</td><td>Type: Delta
Description: Change in estimated expected loss is typically going to be the result of an analysis related to a proposed change in risk management strategy, such as a new regulation.
Simple: At the simple level, the PrRA methodology could be employed by eliciting SMEs to estimate changes from the baseline likelihood/consequence estimates.
Moderate: For LOPA/Bowtie, change analysis involves updating the baseline models to reflect the impacts of a proposed change in risk management strategy. These impacts could by modeled by adding/removing barriers, updating barrier effective estimates, or updating initiating event frequencies.
Complex: For ETA/FTA, change analysis involves updating the baseline models to reflect the impacts of a proposed change in risk management strategy. These impacts could by modeled by adding/removing barriers, updating component reliability estimates, adding/removing human actions, updating human reliability estimates, or updating initiating event frequencies.
Method Quality Summary: The following table summarizes the quality of the output for the various simple, moderate, and complex methods.
<table><tr><th rowspan="2">Output Quality Factors</th><th colspan="2">Simple</th><th>Moderate</th><th>Complex</th></tr>
<tr><th>Pairwise</th><th>Pareto, Risk Index</th><th>LOPA/Bowtie</th><th>ETA/FTA</th></tr>
<tr><td>Objectivity</td><td>Low</td><td>Low</td><td>Low/Medium</td><td>High</td></tr>
<tr><td>Precision</td><td>Low</td><td>Low</td><td>Low/Medium</td><td>High</td></tr>
<tr><td>Confidence</td><td>Low</td><td>Low</td><td>Low/Medium</td><td>High</td></tr></table>
Decisions Informed:
• Regulation Prioritization
• Inform Stakeholders
Example Results:
<table><tr><th>Proposed Measure</th><th>Decrease in Risk Level</th></tr>
<tr><td>Require Additional Driller Training</td><td>-100 RIN</td></tr>
<tr><td>Revamp Cementing Requirements</td><td>-50 RIN</td></tr>
<tr><td>Require Additional Valve on BOP</td><td>-40 RIN</td></tr></table></td></tr>
<tr><td colspan="2">DECISIONS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td>Select Strategic Initiatives</td><td>The industry that BSEE regulates is highly dynamic and as the industry continues to migrate into more extreme environments and apply new technologies, there are significant uncertainties in BSEE’s future risk profile. Risk results can help provide BSEE with insights by identifying high risk issues and issues with high uncertainty that require further study in the form of strategic initiatives, which may be internal to BSEE or may be pursued in partnership with industry.
Supporting Outputs:
• Trends
• Ranked List of Dominant Contributors
• System Importance Metrics
• Component Importance Metrics
• Ranked List of Loss Events</td></tr>
</table>

Regulation Prioritization	In a prescriptive regulatory environment, regulators need to ensure that their rules adequately address failures which could lead to major loss events. Risk information can be used to help identify issues (e.g., modes, systems, failures) that are in need of further regulations. In addition, risk information help regulators develop and select the regulatory option which best balances risk reduction and cost of implementation. **Supporting Outputs:** • System Importance Metrics • Component Importance Metrics • Change in Estimated Expected Loss • Prioritized List of Alternatives
Inspection Prioritization	The knowledge and experience of BSEE inspectors vary, and during an inspection, they do not have the time to inspect every system and component on an offshore platform during an inspection. Risk importance metrics can be applied to help standardize inspection efforts by focusing inspectors on the most critical areas of the platform. **Supporting Outputs:** • System Importance Metrics • Component Importance Metrics • Ranked List of Dominant Contributors
Model Enhancements	As risk processes are conducted and results are generated to support decisions, it is essential to establish a feedback loop to improve the models. Lessons learned as part of this effort should be applied to enhance subsequent iterations. **Supporting Outputs:** • All
Inform Stakeholders	Stakeholders (e.g., BSEE personnel, OGA personnel, industry personnel) have different understanding of where risks in OCS oil and gas activities reside. Risk information generated by these processes are very useful in (1) developing a common understanding of the issues and (2) providing a rational framework for communicating why BSEE is pursuing specific measures to reduce risk. **Supporting Outputs:** • All

5.3. Adaptive Resolution

There are significant challenges to developing an operational risk management program within BSEE. BSEE has a broad and evolving set of risks within its mission set and limited resources it can commit to analyzing those risks. BSEE also currently has limitations in the utility of their enterprise data to directly support some of the more complex modeling techniques, particularly in the areas of equipment and human reliability. Given these challenges, BSEE must wisely employ its analytical resources by (1) focusing effort on known high risk issues and those issues with high risk issues that are poorly understood and (2) choosing appropriate methods based on available SMEs and data.

To accomplish this, the evaluation team is recommending an “adaptive resolution” approach, which is illustrated in Figure 33. This approach is similar in concept to NASA’s APA program (Section 3.4) where anomalous conditions with high risk potential are marked for more detailed risk modeling than those that do not have high risk potential.

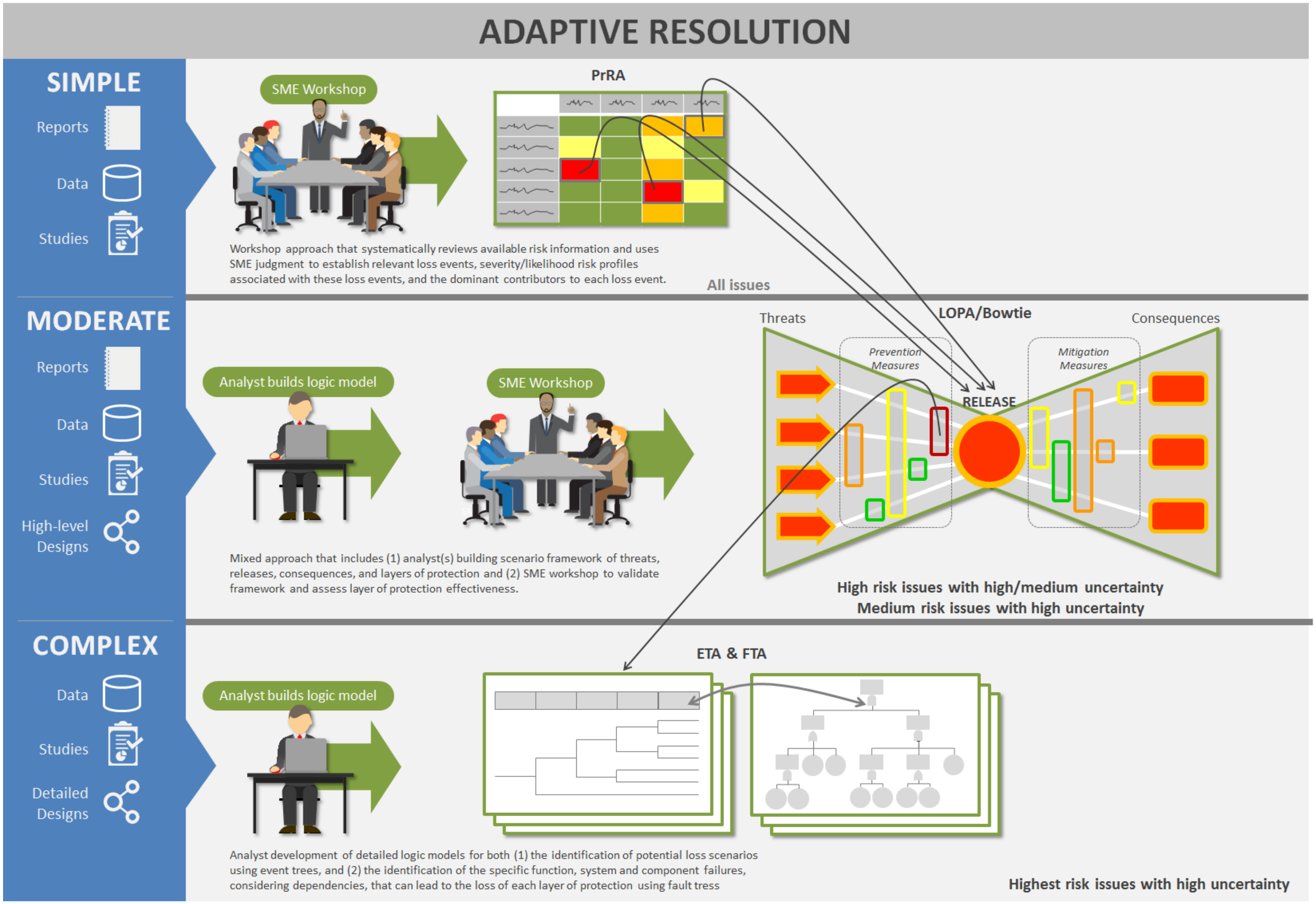


Figure 33. Adaptive Resolution Concept

This approach provides three levels of sophistication to model specific issues or scenarios. The methods build from simple to moderate to complex by screening out issues that do not warrant further analysis as a function of the issue's assessed risk and uncertainty. This helps to ensure analysis is focused on the most important issues (i.e., issues with higher risk and higher uncertainty). Figure 34 provides a decision matrix for how BSEE should respond to issues at each modeling level based on their assessed risk uncertainty. BSEE should seek to reduce high risks regardless of the uncertainty associated with the assessment, but high risk issues with high or medium uncertainty should be studied using further modeling techniques to more fully understand and manage their risk.

	Uncertainty		
Risk	High	Medium	Low
High	Reduce & Study	Reduce & Study	Reduce
Medium	Monitor & Study	Monitor	Monitor
Low	Monitor	Accept	Accept

Figure 34. Risk Management Decision Matrix (Risk vs. Uncertainty)

Note: the "high risk" threshold may change over time. In early risk management cycles, BSEE may have the resources to study only the highest risk issues, but over time, as those issues become well understood, analysis may focus on the next level of issues.

This benefits to this approach are numerous:

- ✓ Optimization of analytical resources by estimating the risk of all known issues at a high-level and focusing in-depth risk modeling on the highest issues
- ✓ Delivering a "quick win" strategic risk profile which puts all issues in context to inform strategic decision making and communication
- ✓ Providing higher quality (precision, accuracy, relevance) risk information for highest risk issues
- ✓ Establishing the foundation to evolve the breadth and quality of risk information over time
- ✓ Leveraging the best available SMEs and data at each level
- ✓ Ensuring alignment among risk analysis processes
- ✓ Identifying data gaps and develops requirements for future data collection
- ✓ Evolving over time to support new decisions

Appendix B provides specific examples of the frameworks that could be employed to implement an adaptive resolution concept.

6. Recommendations

This section recommends a series of phases that BSEE could pursue over time to implement an operational risk management program that employs the adaptive resolution concept. The collection of simple, moderate, and complex risk methodologies presented in the previous section serve as the foundation of this implementation plan. The evaluation team developed this plan based on (1) desirable attributes of the other agency programs, (2) previous experience in developing similar programs for other organizations, and (3) an understanding of the unique aspects of BSEE's mission, organization, decision support needs, available data, and analytical resources. The design of the program is built upon five guiding principles.

Guiding Principles

1. Establish a strong foundation for good decision making
2. Start small and get smarter over time
3. Focus analytical resources on highest risk issues
4. Provide flexibility to meet evolving decision-making demands
5. Perfect is the enemy of good – provide timely and useful risk information

Figure 35 illustrates the key elements of the operational risk management program concept, including the flow of information from inputs through models to generate outputs that support decisions. It also illustrates the various functions to be performed by the various branches and sections within the OORP.

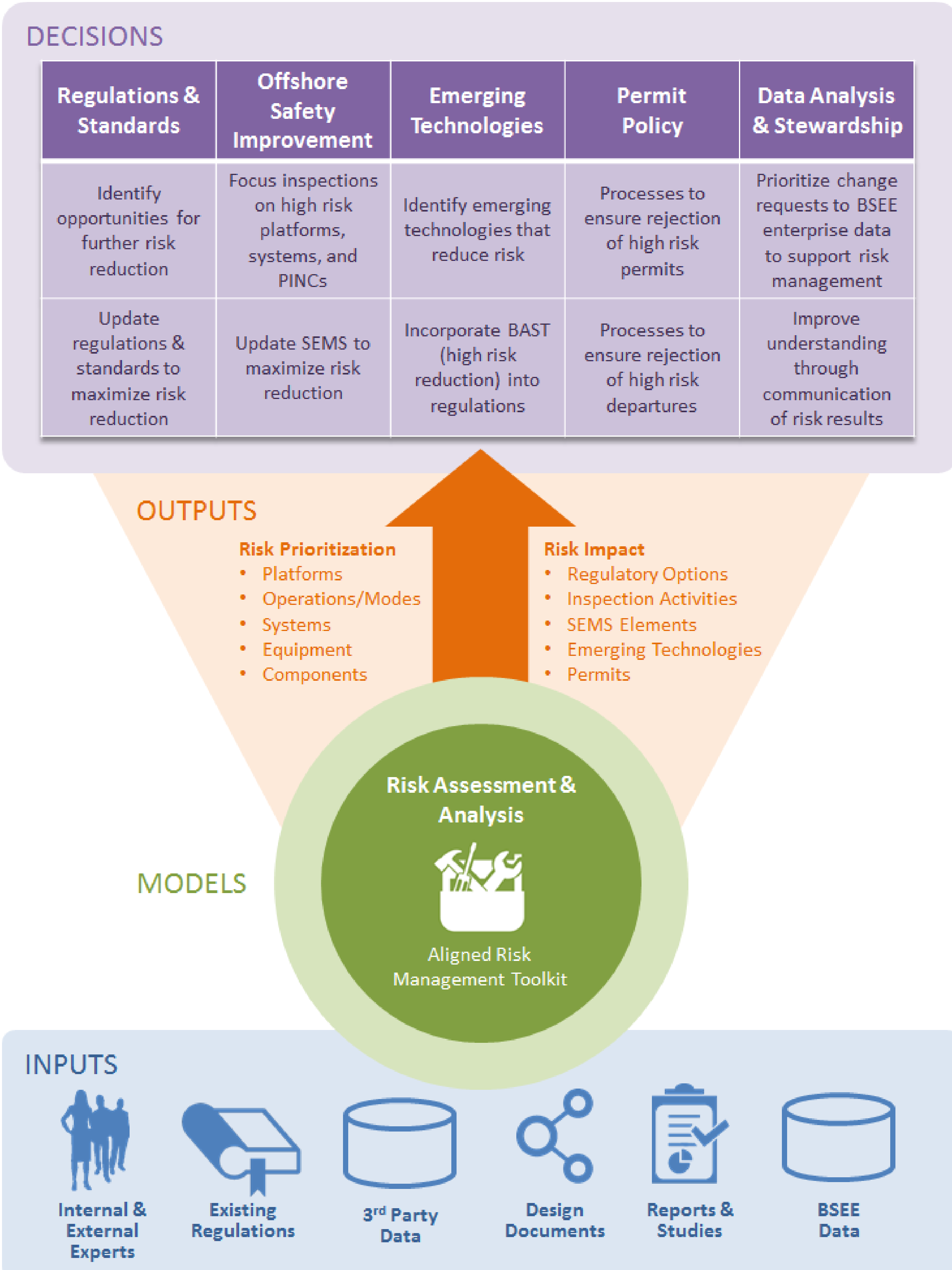


Figure 35. Implementation of the Operational Risk Management Program within the OORP

Developing a mature risk management program that provides useful information to support strategic decision making does not occur overnight; rather, it requires long-term commitment to achieve the desired end state. Therefore, the evaluation team proposes the development of the program through annual analytic cycles. The foundation of the cycle is the annual *OCS Strategic Risk Profile*, which should start with a similar scope and approach as PSA's RNNP and the USCG's NMSRA and develop over time based on BSEE's needs. The *OCS Strategic Risk Profile* would (1) provide a common understanding of risk spanning BSEE's responsibilities, (2) identify issues for moderate and complex risk modeling, (3) identify new/enhanced enterprise data requirements, and (4) provide the foundation for risk-based decision support.

Figure 36 illustrates the annual cycles through a high-level implementation plan for the first two^{+} years, and the following sections will provide details about each of the phases illustrated in the recommended high-level implementation plan.

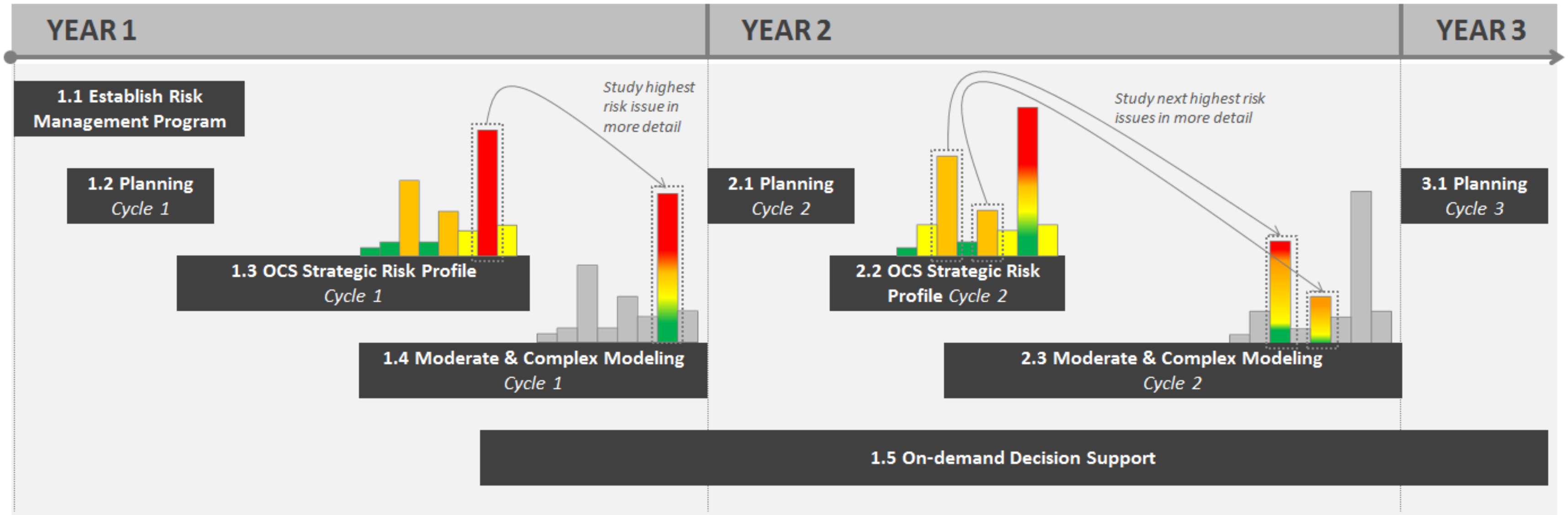
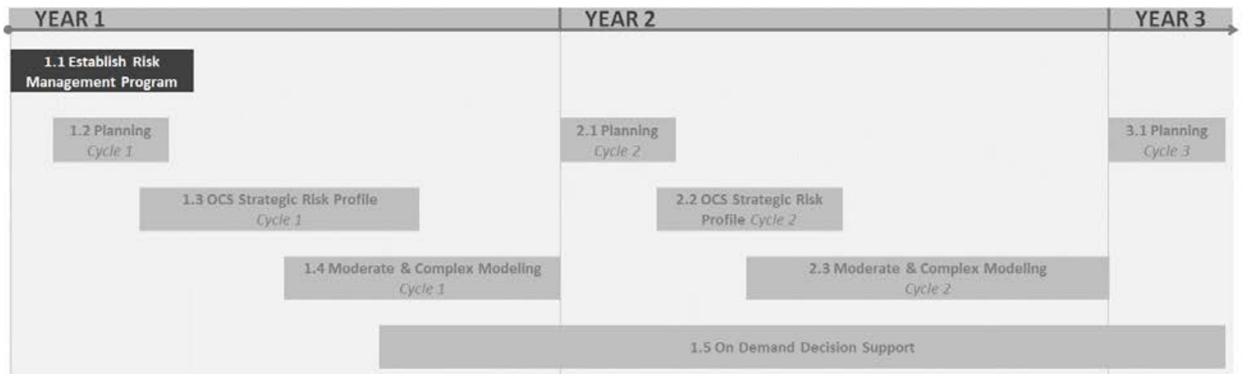


Figure 36. Recommended High-level Implementation Plan (Years 1 and 2⁺)

6.1. Phases: Year One

Table 18 provides an overview of each of the recommended phases to be conducted in the first year by providing an overall phase description, duration, and a summary of key tasks and outputs.

Table 18. Year One Phase Summary

<table>
<tr><td colspan="2">Phase 1.1: Establish Risk Management Program</td></tr>
<tr><td colspan="2">Description</td></tr>
<tr><td colspan="2">Develop a foundation for the implementation and long-term evolution of an operational risk management program. This phase will establish key facets of a successful program, including: organization, policy, processes, methods, tools, and performance measures. This foundation should be endorsed by leadership and in compliance with government regulations and industry best practices.</td></tr>
<tr><td colspan="2">Duration: 4 months</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Tasks</td><td>Description</td></tr>
<tr><td>Program Charter</td><td>Establish charter for the risk management program that addresses: purpose, expected benefits, assumptions, and duration. The charter should be signed by BSEE leadership to formally establish the program.</td></tr>
<tr><td>Risk Management Team</td><td>Establish the risk management team who will be responsible for the oversight of the program. This phase will identify the unique roles and responsibilities within the team.</td></tr>
<tr><td>Risk Maturity Model</td><td>Develop a risk maturity model to serve as a valuable communication and management tool that (1) describes leadership’s vision of a desired end state and (2) serves as a roadmap to realize that vision through a logical progression of maturity levels. The maturity model should address all facets of a successful risk management program, including: alignment with decision-making processes, policy, methods, risk tolerance levels, organization, tools, data, and outcomes.</td></tr>
<tr><td>Risk Lexicon</td><td>Develop risk lexicon to facilitate consistent communication among BSEE personnel and external stakeholders.</td></tr>
<tr><td>Risk Analysis Framework</td><td>Develop all of the required framework elements for each of the methodologies identified for implementation to ensure (1) a sound basis that is relevant to BSEE decision making and (2) alignment, to the extent possible, across methodologies. The framework will address a number of facets of risk assessment, including: scenario definition, likelihood criteria, consequence criteria, mitigation effectiveness, risk calculations, risk tolerance/risk acceptability, uncertainty characterization, and approved data inputs.</td></tr>
<tr><td>Risk Results and Communication</td><td>Develop expected output types for each method and design means for results communication tailored to various audiences. Results could take the form of data, charts, graphs, infographics, heat maps, and interactive displays of risk information.</td></tr>
<tr><td>ALARP</td><td>Define how ALARP principles will be employed within the risk management program. This could take a variety of forms, including development of a BSEE TOR model for the evaluation of specific operations or mission-wide annual expected loss thresholds.</td></tr>
</table>

Performance Measures	Develop suite of risk management program performance measures to support management of the program over time. This task will leverage the risk maturity model as a means for setting targets and measuring performance against those targets. There should be additional leading and lagging indicators as well as outcome measures that should be leveraged or developed to provide managers with performance indicators.

Outputs

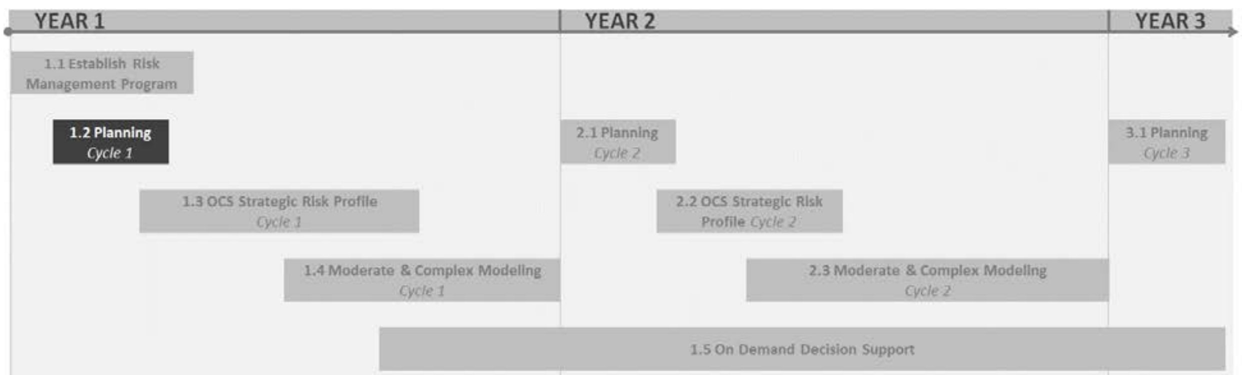
- Foundational policy documents
- Established risk management organization with defined roles and responsibilities
- Established risk lexicon to facilitate consistent communication
- Fully defined risk methodologies prepared for application
- Collection of risk output designs tailored to various audiences
- Suite of performance measures to support program management
- Established performance measures and performance targets

Phase 1.2: Planning – Cycle 1

Description

Plan for the first cycle of the risk management program by defining the desired outputs, budget, timelines, key milestones, resources, and potential roadblocks.

Duration: 2 months



Tasks	Description
Define Potential Objectives of Cycle 1	Define a set of Cycle 1 objectives by identifying (1) what decisions should be supported, (2) what information is needed to support the decisions, and (3) what methods are capable of generating that information. The risk management team should then prioritize the set of objectives based on their criticality to achieving program goals.
Determine Available Resources	Identify available government and contracted resources to support Cycle 1 of the program.
Scope Cycle 1	Identify which of the objectives can be achieved based on the available resources and document the formal scope of Cycle 1. Include any key external dependencies or potential roadblocks that may affect project execution. Lower priority objectives that cannot be achieved in Cycle 1 given constraints should be tracked as enhancements for implementation in subsequent cycles.
Develop Project Plan	Develop detailed project plan based on the scope by documenting: project timeline, sequence of key tasks, dependencies among tasks, assigned resources, expected outputs, milestones, and deliverables.

Outputs

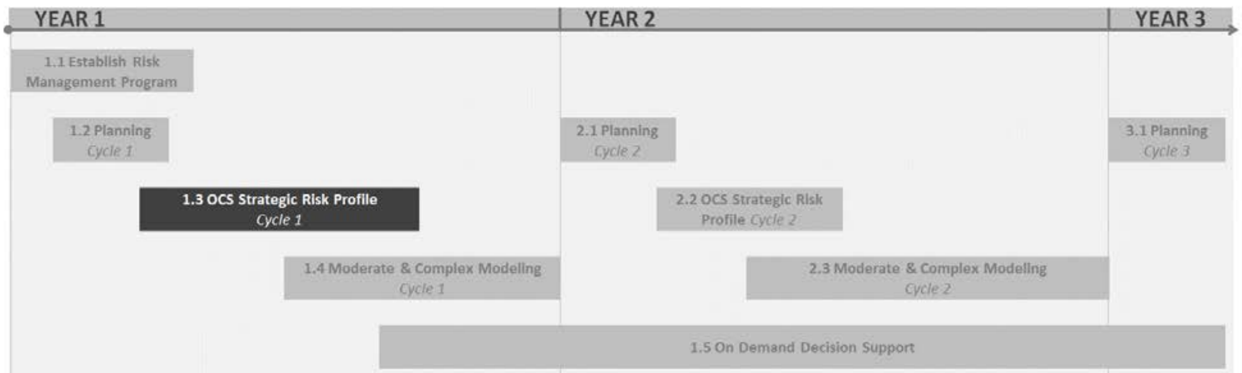
- Defined objectives for Cycle 1
- Detailed project plan
- List of potential enhancements for future cycles

Phase 1.3: OCS Strategic Risk Profile – Cycle 1

Description

Develop a coarse understanding of risks spanning BSEE's mission set. The effort will leverage the best available internal and external data and SMEs applied through the simple PrRA methodology to generate qualitative and quantitative risk information that can be used to support a variety of strategic decision-making processes, including: strategic planning, budgeting, regulatory development, regulatory analysis, inspection prioritization, and permit review.

Duration: 6 months



Tasks	Description
Technical Planning Session	Hold initial meeting to discuss the scope of the project. Document the decisions to be supported by the risk profile, identify who should be involved, and identify available analytical resources.
Select/Tailor Tools to Facilitate Risk Analysis	Leverage PrRA risk methodology framework developed in Phase 1.1. Select the appropriate tools to facilitate PrRA-based risk analysis process (e.g., Excel™, EnterpriseLEADER) and tailor those tools to support the risk analysis process by entering the scenario framework in the tool, adding the likelihood, consequence, and mitigation scoring criteria (categories), adding the risk thresholds, and finalizing the risk calculations.
Gather and Analyze Relevant Data	Research and gather relevant internal and external data, reports, and studies. Analyze and transform the data into a straw-man risk profile based on historical losses recognizing that, for some scenarios, there will be no historical losses. Perform trending analysis of incidents and other risk indicators.
Prepare for SME Elicitation Workshops	Develop plan for SME elicitation workshops by identifying what questions will be asked, how will they answer the questions, how will the risk management team use SME input. Based on the questions, determine if electronic voting software is required (e.g., ThinkTank), and if so, configure the software for the workshop. Break down the various issue-specific sessions that are needed and the specific domains of expertise required for each session. Identify internal and external SMEs with the appropriate experts for each session and send out workshop invitations. Prepare workshops materials, including: presentations, handouts, and supporting data packages organized by session and scenario to facilitate efficient risk analysis.
Host Elicitation Workshops	Host the facilitated risk analysis workshop made up of a number of issue-specific sessions covering a comprehensive set of scenarios spanning BSEE's mission. During these sessions, a facilitator will elicit various types of information from the SMEs, including: • Validation of scenarios • Identification of any new scenarios • Judgment on the likelihood and consequences of scenarios • Characterization of their uncertainty in their assessment • Identification of key risk drivers and trends for each scenario

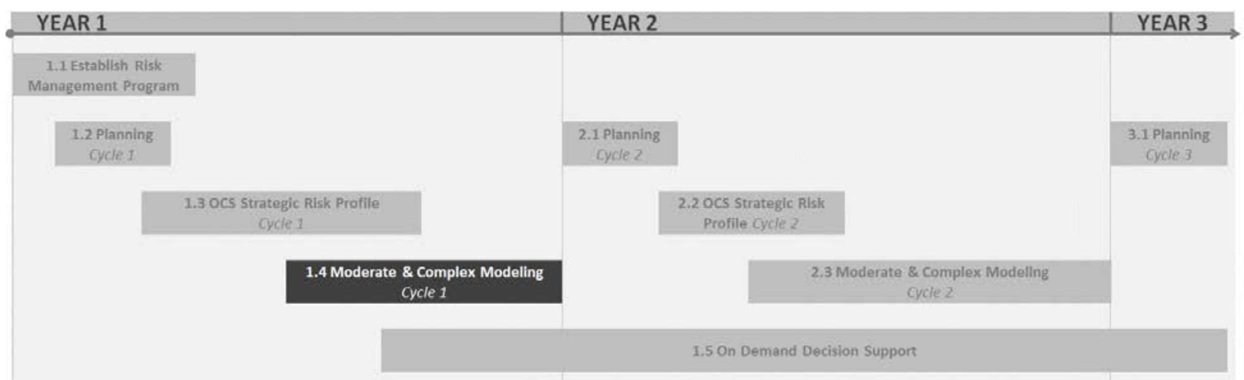
Generate Results	Generate results based on the information gathered during the data analysis and workshop steps. The results should be communicated based on the recommended methods defined in Phase 1.1 and should address a variety of facets of the risk profile, which could include, but are not limited to: • Trends of accidents, consequences, and leading indicators • Summary of key drivers • Risk (expected loss) estimates viewed by a number of facets, such as o Consequence type (environmental, death/injury) o Severity level (minor, catastrophic) o Operation type o Incident type o Certainty level The results will be documented in the chosen format, which could include an OCS Strategic Risk Profile Report and a presentation.
Identify Issues for Further Analysis in Cycle 1	Identify candidate issues for more complex analysis (in Phase 1.4) based on risk estimates and assessed uncertainty level. Issues with the highest combination of risk and uncertainty are best candidates for more detailed modeling.
Solicit Participant Feedback	Solicit feedback and ratings via surveys and interviews from those that participated in the project, including: decision makers, risk analysts, and SMEs. The feedback should address every element of the project, including: overall objectives of the assessment, risk assessment process, judgments, supporting data, tools, workshop facilitation, and results.
Document Lessons Learned	Document lessons learned based on the participant feedback and identify potential enhancements for subsequent cycles.
Document Enhanced Data Requirements	Phase 1.3 tasks will leverage the best available internal and external data, but to improve the process for subsequent cycles, document requirements for enhancements to BSEE enterprise data collection. Provide requirements to owners of BSEE data systems for their consideration.
Outputs	
• Existence of a strategic risk profile that can be used to support strategic communications (e.g., BSEE Annual Report) and strategic decisions • Supporting qualitative information to provide context • Identified issues for more complex modeling (Phase 1.4) • Lessons learned and enhancement ideas for the next cycle	

Phase 1.4: Moderate & Complex Modeling – Cycle 1

Description

Develop a better understanding of the small set of high risk and high uncertainty issues identified in Phase 1.3. The effort will leverage the best available internal and external data and SMEs applied through the more complex Bowtie, ETA, and FTA methodologies to generate more precise quantitative risk information that can be used to support a variety of decisions

Duration: 6 months



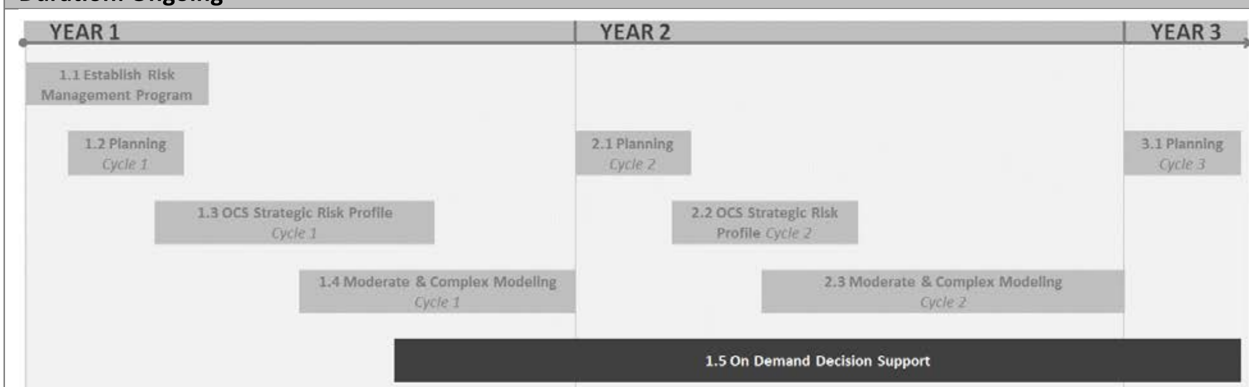
Tasks	Description
Technical Planning Session	Hold initial meeting to discuss the scope of the project. Document the decisions to be supported by the risk profile, identify who should be involved, and identify available analytical resources.
Select/Tailor Tools to Facilitate Risk Analysis	Leverage Bowtie, ETA, and FTA risk methodology framework developed in Phase 1.1. Select the appropriate tools to facilitate the risk analysis process (e.g., Thesis, RISKMAN) and tailor those tools to support the risk analysis process by entering the scenario framework in the tool, adding the likelihood, consequence, and mitigation scoring criteria (categories), adding the risk thresholds, and finalizing the risk calculations.
Develop Straw-man Bowtie Model	Research and gather relevant internal and external data, reports, studies, and design documents. The coarse risk information, both qualitative and quantitative, generated in Phase 1.3 will also be a key input. Analyze and transform the data into a straw-man Bowtie risk profile based on the information, by: • Identifying threats for each scenario • Estimating likelihood of threats by leveraging historical accident rates based on BSEE and other data sources (e.gl, SINTEF, WOAD) • Identifying unwanted events (e.g., loss of containment, fire/explosion) based on an understanding of historical accidents from BSEE and other data sources • Characterizing various consequence types (e.g., environmental, death/injury) and their severity potential based on historical accidents in BSEE and other data sources • Identifying layers of protection (barriers) designed to both prevent the accident from occurring and mitigating the consequence if it does occur • Estimating the effectiveness of each layer of protection for each scenario based on BSEE and other data sources (e.g., OREDA)

Prepare for Bowtie SME Elicitation Workshops	Develop plan for SME elicitation workshops by identifying what questions will be asked, how will they answer the questions, how will the risk management team use SME input. Based on the questions, determine if electronic voting software is required (e.g., ThinkTank), and if so, configure the software for the workshop. Break down the various issue-specific sessions that are needed and the specific domains of expertise required for each session. Identify internal and external SMEs with the appropriate experts for each session and send out workshop invitations. Prepare workshops materials, including: presentations, handouts, and supporting data packages organized by session and scenario to facilitate efficient risk analysis.
Host Bowtie Elicitation Workshops	Host the facilitated risk analysis workshop made up of a number of issue-specific sessions covering a comprehensive set of scenarios spanning BSEE's mission. During these sessions, a facilitator will elicit various types of information from the SMEs including: • Validation of scenarios and identification of any new scenarios • Validation of threats and identification of any new threats • Judgment on the likelihood and consequences of scenarios • Judgment on the effectiveness of layers of protection • Characterization their uncertainty in their assessments

Generate Bowtie Results	Generate results based on the information gathered during the data analysis and workshop steps. The results should be communicated based on the recommended methods defined in Phase 1.1 and should address a variety of facets of the risk profile, which could include, but are not limited to:
	• Risk (expected loss) estimates viewed by a number of facets, such as
	    o Consequence type (environmental, death/injury)
	    o Severity level (minor, catastrophic)
	    o Initiating event
	• Risk importance of layers of protection within and across scenarios
	
	The results will be documented in the chosen format, which could include a report and a presentation.

Identify Issues for Complex Analysis	Identify scenarios and layers of protection for more complex analysis based on risk estimates and assessed uncertainty level. Issues with the highest combination of risk and uncertainty are best candidates for more complex modeling.
Develop ETA/FTA Model	Research and gather relevant internal and external data, reports, studies, and design documents. The coarse risk information, both qualitative and quantitative, generated in Phase 1.3 and the Bowtie risk information, generated earlier in this Phase, will also be key inputs. Develop event trees and fault trees based on the information, by identifying the failure logic for each accident scenario, including the initiating event and failure of various layers of protection. The failure logic will identify the collection of component and human failures that can lead to a failure of the layer of protection. The fault trees will identify component, and to some extent layer of protection, redundancies and common cause failures.

Generate ETA/FTA Results	Generate results based on the ETA/FTA. The results should be communicated based on the recommended methods defined in Phase 1.1 and should address a variety of facets of the risk profile, which could include, but are not limited to:
	• Risk (expected loss) estimates viewed by a number of facets, such as
	    o Consequence type (environmental, death/injury)
	    o Severity level (minor, catastrophic)
	    o Initiating event
	• Risk importance of layers of protection within and across scenarios
	
	The results will be documented in the chosen format, which could include a report and a presentation.

Solicit Participant Feedback	Solicit feedback and ratings via surveys and interviews from those that participated in the project, including: decision makers, risk analysts, and SMEs. The feedback should address every element of the project, including: overall objectives of the assessment, risk assessment process, judgments, supporting data, tools, workshop facilitation, and results.
Document Lessons Learned	Document lessons learned based on the participant feedback and identify potential enhancements for subsequent cycles.
Document Enhanced Data Requirements	Phase 1.4 tasks will leverage the best available internal and external data, but to improve the process for subsequent cycles, document requirements for enhancements to BSEE enterprise data collection. Provide requirements to owners of BSEE data systems for their consideration.
Outputs	
• Existence of a more detailed risk profile for select issues that can be used to support communications and decisions • Layer of protection importance measures to inform regulations and inspections • Lessons learned and enhancement ideas for the next cycle	
Phase 1.5: On Demand Decision Support	
Description	
Apply the results of risk information generated in Phases 1.3 and 1.4 to improve decision making throughout the organization. This phase provides an ongoing, on-demand risk management technical support function where the risk management team makes use of available risk information to support decision making. The team will choose the appropriate method(s) from the framework developed in Phase 1.1 to meet specific decision support needs. Early in the phase, support is expected to be ad-hoc, as the risk management team develops tailored processes and results to meet various demands. Over time, it is expected that much of the support will become standardized to generate information serving as inputs to standard business processes, such as BSEE's annual report, strategic planning, and budgeting cycles.	
Duration: Ongoing	
	
Tasks	**Description**
Provide Helpdesk Support	Provide ongoing helpdesk support to the risk management program user community by answering questions to help analysts, SMEs, and decision makers understand and apply risk information. This support could include answering questions about methodology, tool usage, results and how results could be applied. In addition, the help desk could generate tailored results for users by filtering on existing datasets. If users require support in generating additional risk information or facilitating a risk or changes analysis, the helpdesk could support ad hoc projects.

Ad Hoc Risk/Change Analysis Projects	
Technical Planning Session	Hold initial meeting to discuss the scope of the project. Document the decisions to be supported by the risk profile, identify who should be involved, and identify available analytical resources.
Select/Tailor Tools to Facilitate Risk Analysis	Choose the appropriate risk methodology from those developed in Phase 1.1. Select the appropriate tool(s) to facilitate the analysis process and tailor it to the specific needs of the project
Gather and Analyze Relevant Data	Research and gather relevant internal and external data, reports, and studies. Analyze and transform the data into a useful construct for the project
Prepare for SME Elicitation Workshops, if necessary	Develop SME elicitation workshop plan by identifying what questions will be asked, how will they answer the questions, and how will the risk management team use SME input. Based on the questions, determine if electronic voting software is required (e.g., ThinkTank), and if so, configure the software for the workshop. Identify internal and external SMEs with the appropriate experts for each session and send out workshop invitations. Prepare workshops materials, including: presentations, handouts, and supporting data packages to facilitate efficient risk analysis.
Host Elicitation Workshops, if necessary	Host a facilitated risk analysis workshop where facilitator elicits the required information from the collection of SMEs.
Generate Results	Generate results based on the information gathered during the data analysis and workshop steps. The results should be communicated based on the recommended methods defined in Phase 1.1 and should address the output requirements. The results will be documented in the chosen format, which could include an OCS Strategic Risk Profile Report and a presentation.
Solicit Participant Feedback	Solicit feedback and ratings via surveys and interviews from those that participated in the project, including: decision makers, risk analysts, and SMEs. The feedback should address every element of the project, including: overall objectives of the assessment, risk assessment process, judgments, supporting data, tools, workshop facilitation, and results.
Document Lessons Learned	Document lessons learned based on the participant feedback and identify potential enhancements for subsequent projects and risk management cycles.
Document Enhanced Data Requirements	Ad hoc projects will leverage the best available internal and external data, but to improve the process for subsequent cycles, document requirements for enhancements to BSEE enterprise data collection. Provide requirements to owners of BSEE data systems for their consideration.
Outputs	
• Supported users, which over time, build a strong RBDM capability and risk management culture within BSEE • Tailored risk and change analysis results to improve decision making • Lessons learned and enhancement ideas for the next cycle.	

6.2. Phases: Year Two⁺

Each annual cycle will include the major phases described in Section 6.1 for the first year with the exception of the *Establish Risk Management Program* task. At the start of each annual cycle, the risk management team will plan for the annual cycle based on demand for increased decision support, lessons learned from previous cycles, and new/enhanced enterprise data. With each annual cycle, BSEE risk information will increase in quality and scope. Over time the effort expended to develop the *OCS Strategic Risk Profile* will decrease and more effort will be spent on moderate/complex risk modeling and decision support.

6.3. Data Collection: Supporting Tomorrow's Decisions

Each modeling phase described in Sections 6.1 and 6.2 includes a *Documenting Enhanced Data Requirements* task. This reflects the fact that improved risk analysis requires enhanced data. One of the keys to an integrated process will be the collection and maintenance of well-organized data that are applicable to various analyses and decision types. The program will also require systems to be in place for accumulating and distributing the output information to decision makers.

6.3.1. Current Status

The data that BSEE currently collects are sufficient for a wide variety of BSEE oversight tasks. However, as BSEE oversight becomes more targeted and risk-based, data inadequacies will arise. The evaluation team has identified several weaknesses in the current enterprise data to support risk-based targeting of oversight activities, including:

- Event failure sequences are difficult to identify
- Equipment failures lack a consistent classification taxonomy
- Loss severity levels are inconsistently recorded
- Risk exposure at a system- or equipment-level is not available
- Safety culture and human factors are not assessed
- Compliance level data (for SEMS and other regulations) are not available

These weaknesses are not all equally significant. Some of them may be overcome through use of generic industry data. Solutions to fill these gaps will enable better understanding of risk and more sophisticated approaches to risk management.

On the positive side, BSEE's incident and INC data contain large amounts of information. Some of it, after detailed analysis and data conditioning, can inform complex modeling techniques. A key component of the first cycle planning phase (Phase 1.2) will be taking stock of what data are available. Because BSEE does not perform a wide variety of risk analysis, it has not yet extensively explored the applicability of its own enterprise data or other generic industry data sources for risk data.

6.3.2. Early Cycles (1 to 3) – Data Development

The early risk modeling cycles will be characterized by several new data-related functions. First, data will be collected to support various modeling processes. Second, information output by risk models will need to be organized and housed for easy access by decision makers. Third, as BSEE begins to explore near-miss and real-time monitoring data, anticipation of how to leverage these sources for risk-based decision making will be important. Finally, BSEE will need to consider what data might be needed to support future potential methods of assessing regulatory effectiveness.

For a given analysis, there are at least four possible options to satisfying the need for supporting data:

- Locate data within existing BSEE databases.
- Use SMEs to supplement data gaps
- Use generic industry data to close data gaps
- Use less objective methods until data can be collected

None of these options must be pursued exclusively and many analyses will blend these approaches. During Phase 1.3, BSEE will be required to consolidate existing data for analysis within the strategic risk assessment. Because phase 1.3 is very high level and heavily reliant on SMEs, existing gaps in BSEE's enterprise data will not likely inhibit model development. Step 1.3 will identify areas of risk for possible moderate or complex analysis. This is the point where data limitations may arise.

Most moderate or complex models work best with specific, objective data. When these data are unavailable from BSEE's existing databases, the analysis might be able to continue using SME and generic industry data to supplement. However, this is the point at which BSEE should consider collecting relevant data internally.

Before beginning to collect any kind of data, BSEE should consider whether similar data might be required in the future for analysis related to other facilities, systems, incident types, etc. Whenever possible, new data collection should leverage standard taxonomies for categorizing equipment, failures, initiating events, human errors, risk scenarios, and historical event sequences. Data tables should also be structured in such a way that they will be applicable beyond the specific scenario being analyzed. Accommodation for future analysis will help streamline data collection and help focus future resources on analyses to improve risk knowledge rather than additional data collection.

Data collection requires resources and may prove difficult when the data must be garnered from industry. However, in light of the amount of data that is currently being collected, the evaluation team suggests that existing data collection mechanisms might be modified in order to capture better risk data. For example, inspection findings and incident investigation reports currently contain a large amount of data. Some of these data are already useful for risk analysis, but the most valuable risk data are often captured in free text data fields. This enables detailed recording of data, but makes analysis extremely costly and difficult. A significant element of enhancing the data collection for risk analysis might include standardization of how this data are recorded.

For example, when an incident investigation takes place, the investigator currently develops an investigation report. The investigation report contains very useful data about the sequence of equipment and/or human failures that lead to the incident. In the process of developing the report, it could take little additional effort from the investigator to put the data into an incident sequence database using a series of dropdown menus and survey-type questions to identify the categories of equipment and failures involved. Such a systematic survey could also help ensure consistent levels of reporting detail. For loss of well control incidents, it would ensure that information is collected on specific well conditions and on the well's identification information.

An overarching goal would be that superfluous data would not be collected, but that data collection would not be so specific that one project's data would not be compatible with another project's data.

A similar mindset applies on the maintenance and organization of information produced by various risk models. Different risk models produce different kinds of information. However, risk models should be oriented in such a way that results of a risk analysis performed in one area is comparable to results produced in another area and that both sets of results would be easily accessible to decision makers. Standardizing data collection for various analyses is a key step in aligning outputs.

The availability of new data for BSEE analysis will shape the risk methodologies that can be employed. The new near miss reporting system might open up a better understanding of initiating event frequencies; and therefore, BSEE could employ more complex methods, such as ETA/FTA for understanding risk. If BSEE chooses to pursue real-time monitoring of offshore operations, this too would affect the kinds of methods that could be employed. Live data, though perhaps requiring substantial analytical load, might give BSEE just what it needs to understand risks and preempt losses in a much more timely fashion.

Finally, assessment of risk reduction effectiveness is the ultimate challenge of any regulatory regime. Although it is difficult to guarantee success in measuring effectiveness, some types of data might help in understanding regulatory effectiveness. First, quantitative measures about the level of compliance with regulation of operators and facilities are a key piece in understanding effectiveness. If there is no correlation between compliance levels and risk performance, perhaps the regulations are ineffective. Worker survey data, as collected by PSA for its RNNP project, might also be helpful. Aggregation of worker opinion related to the impact of regulation on safety may provide a unique perspective on effectiveness. Finally, incident data should specifically indicate if legal violations led to loss. The evaluation team has noted this type of information in BSEE's incident reporting data, but it is unclear whether it is consistently available and useful. Any loss that occurs without violation of law indicates a potential area of regulatory ineffectiveness. Effectiveness is very difficult to assess, but consistent collection of this type of data over a period of time may eventually contribute to improved understanding.

6.3.3. Late Cycles (5 to 10) – Data Maturity

After several annual cycles, data collection should stabilize. Most risk assessments should be able to tap into existing data. More importantly, risk information should accumulate as, year-to-year, existing risk models are more efficiently executed and additional analysis enables the expansion of application to other BSEE functions.

Appendices

A. Methodology Descriptions

A.1. Trend Analysis

A.1.1. Summary

Trend analysis is a simple, objective risk assessment. The key feature of trend analysis is that it is time-oriented—the analysis helps identify risks changing over time. While the frequency of events and the quality of data in the analysis largely determine how predictive the results will be, there are techniques for configuring the analysis to maximize interpretability and applicability.

Trend analysis can be used in a variety of ways. It can be used as a high-level "dashboard" type summary of a metric over time. Trend analysis can also be used predictively; a consistent, steady change in a metric from period to period might indicate that the change can be expected to continue into the future. More interestingly, trend analysis might be used as an exploratory tool; an unexpected change in the trend might help justify future study of a risk or contributing factors to the metric. Side-by-side comparisons of trends of different measures can help the user to identify correlations between values as they both change over time.

Trend Analysis

- Time-oriented plot of historical data for visual interpretation
- Simple methodology
- Objective, with very little SME input
- Analysis can be performed by a single analyst
- Most applicable to high level "dashboard" type understanding of risk

A.1.2. Limitations

Least valuable for understanding low frequency, high consequence events. For events that occur frequently and have "predictable" consequences, trend analysis can be used to identify whether the frequency of events or the severity of outcomes are changing in any stable way. For events that rarely occur, trend analysis is often less useful since extreme events tend to skew the picture.

Only applicable to objective data. Trending analysis is by definition highly numerical. Bowtie analysis and fault tree analysis can aid people in discovering possible risk sequences or failure modes which have never even occurred. Trend analysis, on the other hand is generally used to report historical risk levels. It answers the questions "When?" and "How much?" for past time periods, rather than "Why?" or "How?"

A.1.3. Procedure

Trend analysis is primarily a means of visualizing data for interpretation. Unlike many other risk methods, very little effort is required to gather SME opinions or to model equipment or human behavior. Trend analysis requires the following steps

1. Collect data
2. Clean/Process data
3. Graph data
4. Interpret results/Identify outliers

Collect data

The process of collecting data for a trend analysis is straightforward. Often, the decision to perform trend analysis comes after the supporting data has already been collected and is available. Good trend data includes a time index and additional fields with values for grouping the records or containing quantitative values[23] for analysis.

Clean/Process data

Trend-relevant data may need to be conditioned prior to being graphed. Grouping the data into time periods is one of the most important steps for successful trend analysis. Some data may already be grouped. In such a case, an observation recorded on a specific day in 2014 may simply be grouped with other 2014 data. When the record contains the specific date and time information, it enables the analyst to select a time period to maximize the interpretability and applicability of the analysis. Figure A1 demonstrates this with three trend analyses of the same data.

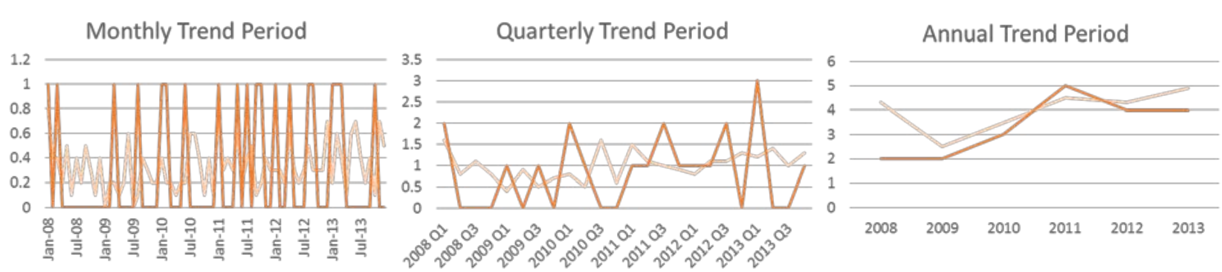


Figure A1. Varying Trend Periods

The first graph shows the data grouped by month. With this grouping, it is difficult to identify any patterns in the data, even though the graph provides a high level of detail. The second graph shows the data grouped by quarter. It provides a better indication of the trend and a moderate level of detail. The final graph shows the least amount of detail with an annual trend period. However, it provides the clearest view of the long term changes being analyzed.

Besides time groupings, data being analyzed may include fields that identify groups of records that warrant separate trend analyses or comparisons. In the offshore context, these groupings might be

[23] In the absence of quantitative values, it may be possible to simply count records in categories based on non-quantitative fields within the data so that the record counts can be analyzed.

based on incident types, platform characteristics, etc. Care should be taken not to split the data so much that the data loses statistical significance.

Graph data

Data may need to be grouped specially depending on the graphing application being used in the analysis. Graphing enables the analyst to process the data visually, enabling better understanding of the trends. Line graphs or bar charts are useful tools for plotting trend data. The graphs should be set up carefully, with axes and other plot elements configured to simply display the data without distortion. In most cases, logarithmic axes make it difficult to interpret the results.

Interpret results/Adjust for Outliers

Trend analysis is not sophisticated. When unexpected results are observed, it is often important for an analyst to interpret the results of the analysis and to understand possible causes for unexpected results. Sometimes, it may be appropriate to remove select data from the analysis in order to adjust for outliers caused by one-of-a-kind events that aren't anticipated to recur. For example, a hundred-year storm might cause a large number of incidents in one year. In such a case, adjusting for the impact that the storm has on incident counts may be appropriate in order that only data that contributes to the predictability of the analysis is included. All such adjustments must be documented.

A.2. Pairwise Comparison

A.2.1. Summary

Pairwise comparison is a method for ranking items in a list when there may not otherwise exist robust values for determining preference of any given item over another. The process relies on the opinions of SMEs who, rather than ranking the whole list of items, are tasked with comparing pairs of items, one pair at a time. In the end, the results of each pairwise comparison are aggregated to arrive at a comprehensive ranking. The simplest method of a pairwise comparison would be comparing two entities. Complexity arises as more entities are included and multiple pairs must be created to ensure each possible pairing is created.

Pairwise Comparison

- Structured approach for ranking items through evaluation of one item pair at a time
- Simple methodology
- Highly subjective results
- Often used to support other methods/models that lack robust data
- Result quality dependent on the knowledge of participating SMEs

While it can be used as simply as determining the preference of a particular candidate but can also be used for more complex analysis of preference such as determining a particular material to use during construction.

A.2.2. Limitations

Analysis process is not scalable to large numbers of items. As mentioned previously, a pairwise comparison looks at two variables at a time. Even when there is a moderate number of items to review, the number of unique pairs can become prohibitively high.

Analysis produces ordinal ranking. Standard pairwise comparisons only capture the SMEs' understanding of ordinal differences in items. If cardinal ranking is required, more complex analyses are needed.

Ranking is purely subjective. When identifying the preference of a particular item, each preference is based on the particular reviewer. If multiple users conduct pairwise comparisons, there is the potential for varying preferences and varying results. Therefore, additional methods may need to be employed to normalize the results or to determine which preferences are more applicable or better suited for the particular scenario.

A.2.3. Procedure

The basic pairwise comparison procedure is straightforward:

1. From a list of items to be ranked, identify all possible pairs of items.
2. For each pair, the SME assigns 1 point to the higher-ranking item and no points to the lower-ranking item. Both items get half a point in the event of a tie.
3. The points from each pair-by-pair scoring are added up for each item.
4. Items are ranked based on their total score.

The tables below illustrate an example pairwise comparison analysis. Table A1 shows how three SMEs ranked items A, B, and C in each pairing. In this example, none of the SMEs agree in their assessments of the items, and SME 3's conclusions are self-conflicting. This does not keep the analysis from being successful, however.

Table A1. Example SME Pairwise Comparison Assessments

Pairing	SME 1	SME 2	SME 3
A/B	A > B	A = B	A > B
A/C	A > C	A > C	A < C
B/C	B = C	B > C	B = C

Table A2 shows how the SME rankings are converted to scores for the items in each pairing.

Table A2. Scoring of SME Assessments

Pairing	SME 1	SME 2	SME 3
A/B	A = 1	A = ½, B = ½	A = 1
A/C	A = 1	A = 1	C = 1
B/C	B = ½, C = ½	B = 1	B = ½, C = ½

Table A3 aggregates the results from and allows the analyst to observe the aggregated ranking of the items. Item A is highest rank, while C is lowest.

Table A3. Aggregated Pairwise Comparison Scores

	A	B	C
SME 1	2	½	½
SME 2	1 ½	1 ½	0
SME 3	1	½	1 ½
Total	4 ½	2 ½	2

It is also possible to modify the pairwise comparison in order to try to allow for more accurate comparisons. One such method of employing more complex analytic methods is the Analytical Hierarchy Process. This process will compare two entities to one another but with greater specificity to include the degree of preference on one entity over another. This will help in ranking the items against each other but will also help rank the items on a more discreet level to help prioritize them.

For this example of a more complex pairwise analysis, a different scoring methodology is used. The score of 1 will be given when candidates are equally matched, 3 is given to the candidate that is slightly more preferred and 1/3 is given to the candidate that is slightly less preferred. 5 is given to the candidate that is significantly more preferred and 1/5 is given to the candidate that is significantly less preferred.

Table A4. Modified Pairwise Comparison

	A	B	C	Total
A	1	0.33	5	**6.33**
B	3	1	3	**7**
C	0.2	0.33	1	**1.53**

Table A4 provides an example of a pairwise comparison modified to give a better sense of the magnitude of the ranking differences between each item. The table gives the preference of the row item over the column item. The total column tallies up the total preference for each row item. It can be clearly seen from this analysis that A and B are similarly ranked while C is considerably lower ranked.

A.3. Relative Ranking/Risk Indexing

A.3.1. Method Summary

The relative ranking/risk indexing technique systematically assesses alternatives based on various factors, generating a risk index number for each alternative. Each index number is calculated using a formula such as:

$$Ranking\ Index = f(Factor_1, Factor_2, \ldots)$$

Where "Ranking Index" is the index number and each "$Factor_n$" represents a different attribute of the alternatives being evaluated. An ideal ranking function will produce index numbers that are correlated with actual risk performance of each alternative. The key is selecting a ranking function that adequately captures and balances the nuances of risk within the analysis scope.

Relative Ranking/Risk Indexing

- Produces an easy-to-use formula for assigning a relative risk score
- Simple to moderate modeling process
- Produces objective, but not necessarily accurate, results
- Output quality varies with the quality of the evaluation tool and the level of effort spent on its development

A.3.2. Method Limitations

The relative ranking/risk indexing technique can provide a high-level assessment of the risks associated with a range of activities; however, the following are a number of limitations that should be considered before selecting this method:

Results can be difficult to tie to absolute risks. The relative ranking/risk indexing technique uses various indexing tools to derive risk scores for particular activities. These scores are highly effective for relative comparisons of one activity to another, but do not provide information about the absolute risk associated with activities.

Appropriate ranking tool may not exist. Each relative ranking/risk indexing tool provides a structured methodology for (1) collecting risk-related data, (2) performing specific, often arithmetic, calculations on it, and (3) assessing the resulting index scores derived from the calculations. The tools are typically well documented to allow personnel who are not experts in risk assessment to use them effectively. However, the tools are typically focused on a particular type of risk to be evaluated; if an applicable tool does not exist, resources must be invested to develop one. For simple applications, custom development of a tool may require only day or two of development time. For broader, considerably more development and validation time may be needed.

Does not account for unique situations. Relative ranking/risk indexing tools are specifically designed to focus on a particular type of risk. They are typically well-documented and very structured to allow personnel who are not experts in risk assessment to effectively use the tools. However, the rigid structure and necessity to comply with the structure of a tool makes it difficult to account for situations outside the scope of the particular tool. This may make it necessary to develop a new tool.

A.3.3. Procedure Overview

1. **Define the scope of the study.** Clearly define the activity that will be analyzed and the desired decisions or outcomes expected from the study.
2. **Select the ranking tool that will be used.** The tools used to conduct a relative ranking review vary widely in form and complexity. The analyst can select from among existing tools or may choose to develop one specifically suited for a particular type of application.
3. **Collect scoring information.** Each ranking tool will use different types of information about vessels, facilities, or operations to calculate index values. This information must be reliably collected by the analysis team.

4. **Calculate ranking indexes.** Following the instructions for the tool selected, the analyst calculates risk index numbers and summarizes the results to facilitate comparisons among reviewed areas.
5. **Use the results in decision making.** The results for the study may be used alone or in conjunction with other factors, such as cost. The results may identify the most important contributors to the index numbers and will help the analyst determine if corrective actions or design modifications should be undertaken to reduce the anticipated risk.

The following pages describe each of these steps in detail.

Define Scope of Study

Because the quality of the relative ranking study is strongly dependent on the relevance of the tool used, it is important to clearly define the activity that will be analyzed as well as the desired decisions or outcomes expected from the study. Examples of ways relative ranking studies can be used include:

- **Establishing priorities for conducting inspections**
- **Identifying the individual systems expected to contribute most to accidents**
- **Identifying the attributes that discriminate among competing design, siting, and operating options**
- **Comparing the anticipated hazards of a vessel, system, or facility to others whose attributes are better understood or commonly accepted**
- **Identify decisions to be made.** Every risk assessment activity, regardless of how simple or complex, requires information to aid in the decision-making process. This crucial step is important when developing a relative ranking tool. The analysts and decision makers must clearly identify the types of decisions to be made and the level of information detail necessary to support them.
- **Decision criteria.** The method should provide guidance on interpreting the numerical indexes generated from the data. Relative ranking tools will most often be used to compare the risks of one option to another. These comparisons may be used to (1) rank the risks of selected waterways in order to prioritize risk assessment resources for more detailed analyses, (2) prioritize boarding and inspection activities within a port, or (3) assess the relative risks of locating a toxic material handling dock. After the indexes are calculated, the decision maker should be provided with some guidance on how to interpret the results, with particular attention on how to differentiate between two options if the indexes are similar in value.
- **Practicality of use.** Finally, the method should be practical. Costly data collection efforts can discourage participation in the analysis. Simple data collection efforts, such as compiling information from existing databases, make a tool more practical and efficient to use.

Select/Construct a Ranking Tool

Certain risks have industry standard relative ranking/risk indexing tools. For example:

- Dow Fire and Explosion Index
- Mond Index
- Substance Hazard Index
- Material Hazard Index
- Chemical Exposure Index

For specific assessments for BSEE, it may be unlikely that a standard relative ranking/risk index will be applicable. In such a case, a custom assessment will need to be developed. Table A5 describes the process of constructing a custom relative ranking/risk index tool.

Table A5. Construction of a Relative Ranking/Risk Index Tool

Step	Description
1. Define what the index will represent	The developer must decide whether the risk index is intended to represent the relative frequency of a loss, consequence of a loss, or risk of the loss. The factors to select for a relative ranking will vary depending on the targeted metric.
2. Identify a list of factors that could affect the index	Selection of the key factors affecting the targeted index may take place with input from SMEs or may result from other insights gained through other risk analyses.
3. Identify specific situations for which specific actions are required	Some values for certain factors might automatically require an action, regardless of the relative risk score determined by the analysis. In such a case, the relative ranking/risk index tool should indicate the exceptional circumstances and required response.
4. Characterize the sensitivity and selectivity of measurements for each factor	Each factor should be analyzed for appropriate sensitivity and selectivity with respect to relative risk level. Sensitivity is the quality that a factor produces positive scores for alternatives with overall low risk. Selectivity is the quality that a factor does not produce positive scores for alternatives with overall high risk. Statistical analysis on the correlation of factors with risk level is often appropriate, when available.
5. Select a basic scoring or indexing scheme	The exact scoring method for relative ranking/risk indexing is flexible. Often, the method will fall under either 0-to-X weighted factor scoring or +/- factor scoring. In a 0-to-X weighted factor scoring scheme, each factor is assigned a score between 0 and a max score "X". The ultimate index number equals the weighted average of these scores with weights representing the importance of each factor. The +/- factor scoring method assigns positive or negative values to each factor. The importance of the factor is reflected by the magnitude of the factor score. The total score equals the sum of the factor scores.
6. Develop scoring scales for each factor based on each factor's sensitivity and selectivity	Scoring scales (factor weights or magnitudes) for each factor must be developed. Factors with both high sensitivity and selectivity should receive the most weight because they produce the most effective rankings.
7. Set action thresholds for the index	Define the scores for which risk is determined to be too high
8. Construct the tool from the scoring scales, index calculations, and action thresholds	Relative ranking/risk indexing tools are typically used in the field via a paper worksheet. This requires that the tool be simple to avoid computational mistakes.
9. Validate the tool through test applications and refine it as needed	The tool will likely be used by individuals who are not experts. Because of this, experts should periodically be involved in validating that the tool is producing an indexing consistent with their understanding of key risks. When data are available, correlation analysis on the level of risk to historically calculated risk index numbers is especially relevant.

Collect Data for Scoring

Each ranking tool will use different types of information to calculate index values, depending on the purpose and level of detail required for the assessment. In a facility inspection prioritization, the factors will probably include information related to the facility type, operating mode, environmental conditions, past incident record, or operator. For a determination of whether or not a particular piece of equipment must be replaced, more detailed information related to its runtime, level-of-wear, and maintenance information will probably support the selection of factor values. This information must be reliably collected by the analysis team and entered into the relative ranking/risk indexing tool.

Calculate Indexes

If a published relative ranking method is chosen, the analyst should follow the instructions in the technique guide to perform the evaluation. Site visits and interviews to verify information and to answer questions may be helpful. The calculated risk index numbers should be summarized to facilitate comparisons among areas that have been reviewed.

In most cases, the risk index numbers generated by the evaluation should not be considered accurate reflections of the absolute risks posed by the vessel or facility being studied. Instead, these results should be considered estimates for comparing the relative risk of each.

Make Decisions

The results of the study may be used alone or in conjunction with other factors, such as cost. In addition, the analyst may determine the most important contributors to the index numbers by reviewing the analysis documentation. This should help determine if corrective actions or design modifications should be undertaken to reduce the anticipated risk. In this way, the analyst may identify the specific areas where the safety weaknesses exist and develop a list of action items to correct the problems.

A.4. Pareto Analysis

A.4.1. Summary

Pareto analysis is a prioritization technique that identifies the most significant items among many. It employs the 80-20 rule, which states that about 80 percent of the problems or effects are produced by about 20 percent of the causes.

Pareto Analysis

- Assessment of dominant contributors to failure.
- Uses simple to moderate complexity methods.
- Supporting data is objective, but grouping of data may be subjective.
- Produces quantitative, graphical results.
- About 80% of the problems are produced by about 20% of the causes.

A.4.2. Limitations

Although Pareto analysis is highly effective in identifying the most significant contributors to activity or system problems, this technique has three limitations:

Pareto Analysis focuses only on the past. Data skews representation of low risk/high consequence events. Changes in operating practice or maintenance plans will not be reflected until they have been in place long enough to affect the available historical data.

Variability in levels of risk assessment resolution. Deciding how to group elements of an activity or system for a Pareto analysis is an inherently subjective exercise. It produces significant variability in the time required to perform the analysis and in the level of resolution in the results. Grouping elements at too high a level may mask significant variations among elements in each group. On the other hand, grouping elements at too low a level may falsely indicate relative importances of individual components.

Dependent on availability and applicability of data. The quality of Pareto analyses is completely dependent on the availability of relevant and reliable data for the activity or system being analyzed. A diligent focus on collecting meaningful data is critical to a successful Pareto analysis.

A.4.3. Procedure

1. Define the system or activity of interest.
2. Define the specific risk-related factors of merit
3. Subdivide and screen the activity or system for analysis
4. Collect and organize relevant risk data for elements of the activity or system
5. Plot the data on Pareto charts.
6. Further subdivide the elements of the activity or system

Define the system or activity of interest

Defining the systems and activities of interest includes establishing what intended function is at risk and within which boundaries the risk is being considered.

All risk assessments are concerned with how an activity or system can fail to perform an intended function. A clear definition of the intended functions for an activity or system is, therefore, an important first step in any analysis. This step does not have to be formally documented for most Pareto analyses.

Few activities or systems exist in isolation. Most interact with other activities or systems. By clearly defining the boundaries of an activity or system, the analyst can avoid (1) overlooking key elements of an activity or system at interfaces and (2) penalizing an activity or system by associating other issues with the subject of the study. This is especially true of boundaries that support activities or systems such as electric power and compressed air.

For example, the intended function and boundaries established for a project might be risks to maintaining well control following from failures within drilling equipment, systems, and workers.

Define the specific risk-related factors of merit

Specify the metrics that best characterize the problems of interest. Virtually any metric can serve as the basis for a Pareto analysis. The key is to define the factors of merit that will best help decision makers make more informed decisions. A Pareto analysis can address more than one factor of merit simultaneously, but separate plots must be created for each. In other words, the systems most important for preventing safety events may not be the same systems as those most important for preventing environmental problems.

Subdivide and screen activities or system for analysis

An activity or system may be divided at many different levels of resolution, as illustrated above. Generally speaking, Pareto analyses should try to characterize risk-related performance for an activity or system at the broadest level possible, based on the availability of applicable data. The procedure for subdividing an activity or system for Pareto analysis is typically iterative, beginning with a broad subdivision into major operations or subsystems. A study of hardware failures may start with a breakdown of hardware by system, but then be further divided to identify specific equipment or components within those systems.

This strategy of beginning at the operation or subsystem level helps promote effective and efficient risk assessments by (1) ensuring that all key issues are considered, (2) encouraging analysts to avoid unnecessary detail, and (3) using a structure that helps avoid overlooking lower-level issues (if further subdivision of the activity or system is necessary).

At this stage, only elements of the activity or system that have produced the problem of interest should be included in the Pareto analysis. For example, if the failure of a drilling topdrive does not create risk to well control (the intended function being studied), then topdrive failures should be excluded from an analysis, even if they are within the scope of drilling equipment (the boundary of the analysis).

Collect and organize relevant risk data for elements of the activity or system

This step generally involves two activities:

- Gathering the raw data about events of interest
- Tabulating the data in a convenient format for generating the Pareto charts, as shown in the following example

Plot the data on Pareto charts.

Pareto charts typically portray one factor of merit at a time. Use a dual vertical axis plot with the left axis defining the range for actual values of the factor of merit (e.g., the range of actual accidents for various elements of the activity or system) and the right axis defining the cumulative contribution of the elements.

Arrange the contributing elements along the horizontal axis. Begin on the left side of the horizontal axis by listing the element that contributes most to the selected factor of merit. Then, moving toward the right of the horizontal axis, list each of the other contributing elements successively in decreasing order of their contribution. You may choose to combine several less important elements into an "other" category to simplify your chart. Be sure you do not combine so many elements together that "other" becomes a dominant contributor. Then plot the data.

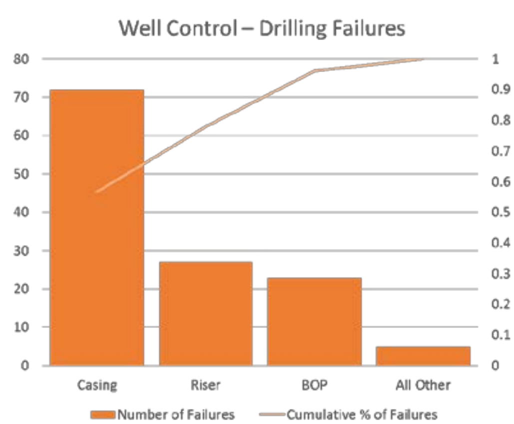


Figure A2. Example Pareto Analysis Plot

Repeat the process for other important factors of merit. Repeat the previous steps for any other factors of merit that are pertinent and for which data have been collected. In this example, another chart could be generated to show the total severity of failures rather than the count.

The "important few" failures can easily be seen on this graph. Certainly, other types of chart formats (e.g., pie charts) can be equally effective for presenting Pareto analysis results. Use the formats with which management feels most comfortable.

Further subdivide the elements of the activity or system

Further subdivision of activities or systems into operations or subsystems occurs only under one of the following conditions:

- Applicable data at an activity or system level are not available
- Decision makers need information at a more detailed level

Often, only a few activities or systems must be expanded. If the above criteria apply to one or more activities, those activities may be further divided into operations. In a similar manner, operations may be divided into functions, functions into systems, etc.

At each level, the process of collecting, organizing, and plotting data is repeated but with the boundary of the analysis reduced to only the category being subdivided.

A.5. PrRA

A.5.1. Method Summary

PrRA is a streamlined accident-centered risk assessment approach. The primary objective of the technique is to characterize the risk associated with significant accident scenarios. In this approach, a team of SMEs filters through available data and information. It promotes systematic review of the issues and facilitates understanding of significant contributors to accidents, potential safeguards, and recommended risk reduction measures.

PrRA

- Survey of risks and dominant contributors
- Simple to moderate complexity
- Can rely heavily on subjective SME input
- Generates quantitative estimates of risk
- Can be used to make high-level risk reduction recommendations and change analyses

A.5.2. Method Limitations

Although PrRA is effective and efficient for identifying high-risk accidents, this tool has two primary limitations:

High-level analysis. The PrRA focuses on potential accidents of an activity; therefore, the failures leading to accidents are not explored in much detail. The high-level, general nature of the analysis introduces a level of uncertainty in the results.

General recommendations. One result of the analysis is the development of recommendations for reducing risk. Due to the high-level nature of the analysis, these recommendations are typically general in nature instead of focused on attacking specific issues.

A.5.3. Procedure

The procedure for performing a PrRA consists of the following five steps. Each step is further explained on the following pages.

1. **Determine the scope of the PrRA.** Determining the scope includes identifying the hazards and activities that will be analyzed.
2. **Screen low-risk activities.** Screening low-risk items streamlines the analysis by eliminating in-depth review of these items.
3. **Analyze accidents.** Evaluating possible accidents, and screening them when appropriate, is the fundamental activity in the PrRA. This involves identifying accidents. It also involves identifying the most significant contributors and safeguards, and characterizing the risk associated with the accidents. Recommendations for reducing risk or reducing uncertainty are also developed.
4. **Generate a risk profile.** The risk information generated from the PrRA can be sorted and reported in a variety of ways to aid in decision making.
5. **Evaluate the benefit of risk reduction recommendations.** Before a recommendation is implemented, the benefit or risk reduction realized from implementing the recommendation should be calculated and considered.

Determine the scope of the preliminary risk analysis

Determining the scope of the analysis involves identifying both the activities of interest that will be reviewed and the hazards that may be present during the performance of each activity.

There are hazards associated with each activity. Associating hazards with activities identifies the specific hazards and accidents the analysis team should be considering as an activity is analyzed.

Screen low-risk activities

Screening allows the analysis team to streamline the PrRA process by identifying low-risk items and eliminating them from the analysis. Screening is a systematic activity that can be performed at any stage of the process.

The activities identified for the risk assessment should be qualitatively reviewed to determine whether the collective frequency of their accidents in all severity categories is less than or equal to screening criteria. Screening criteria are defined by management systems and are the level of risk that management is unwilling to pursue for further risk assessment.

A screening criteria is a set of frequency scores assigned to each accident severity category used in the analysis. To perform the screening step, the analysis team qualitatively reviews the activity and decides whether there are any credible accidents that can occur at a frequency higher than the predefined screening criteria for each accident severity category.

Analyze accidents

PrRA provides a systematic way to analyze accidents that may occur while an activity is performed. For each accident, the analysis identifies both the most significant contributors and the safeguards in place to prevent the contributors or mitigate the accidents. The analysis also defines the risk associated with the accidents as well as recommendations to reduce the risk.

Table A6 describes the steps for filling out a PrRA worksheet. Each step represents a field or group of fields in the analysis.

Table A6. Key Steps in a PrRA Worksheet

Step	Description
1. Identify possible accidents of the activity/screen low-risk accidents	Answer this question when identifying accidents: “While performing this activity, what are the potential accidents that may occur?” An accident is any event that can produce a casualty of interest. Screening of accidents at this stage based on management’s criteria for what risk level merits further analysis enables a more streamlined analysis process.
2. Identify the most significant contributors to accidents	Answer this question when identifying contributors: “While performing this activity, what are the most significant contributors to this accident?” Contributors to accidents can include human errors, equipment failures, hardware system failures, administrative system failures.
3. Identify preventive and mitigative safeguards	Answer this question when identifying safeguards: “While performing this activity, what are the engineered systems or administrative controls in place to reduce the frequency of the contributors or reduce the severity of the accident?” Types of safeguards include hardware (e.g., barriers, alarms, interlocks, redundant pumps), procedures and training, and administrative policies.
4. Determine the frequency of the accident resulting in defined levels of severity	Assess the frequency of each accident occurring at each severity level. A separate field in the worksheet may be used for each severity level. Assess the accident only with respect to the activity being considered. Each frequency estimate should be based on cumulative frequencies of contributing events. In addition to SME judgment, frequencies should be calculated using any data available through accident databases, maintenance database, or generic vendor data.
5. Calculate the risk index number (RIN)	Calculate the average risk index number (RIN) for each accident by using the following equation: RIN = [(F x C) + (F x C) + (F x C) + ...] / 10,000 Where: F = the average frequency for the accident (events per year) C = the average consequence for the accident (dollars per event) Usually, representative values for each of the accident severity categories are defined prior to the analysis. These values can be defined based on historical information or simply defined as the midpoint of each accident severity range. Likewise, the representative frequency for each of the frequency scoring categories is usually set as the midpoint between the upper and lower bounds of the frequency scoring category. While analyzing accidents, the average RIN is the only calculation necessary to quantify and compare risks. However, the lower and upper bounds of the risk index number can also be calculated using the lower and upper bounds of each severity and frequency category. This information is useful for reviewing the entire range of risk associated with an accident.

Step	Description
6. Characterize the certainty of the frequency estimate	To help qualify risk estimates, characterize the confidence in the assessment of the frequency scores for each accident. For example, a medium-risk accident with a High uncertainty may deserve the same or more attention than a high-risk accident with a Low certainty.
7. Develop recommendations	Risk reduction recommendations, and recommendations suggesting more in-depth review, are necessary for high-risk accidents or accidents with low levels of certainty. Risk reduction recommendations should accomplish one or more of the following: • Eliminate or mitigate hazards • Prevent causes (most significant contributors) • Ensure that existing safeguards are dependable • Provide additional safeguards • Mitigate the effects of accidents Some accidents or issues may require a more detailed analysis. Such situations include: • High-risk accidents and issues where more resolution is needed to develop risk reduction measures • Potentially significant accidents and issues with a low level of certainty in the risk assessment or the information gathered about the accident scenario

Generate a risk profile

To manage risk effectively, decision makers must analyze the risk associated with a unit class or facility from several perspectives. The preliminary risk analysis provides risk information for each accident associated with an activity. Risk associated with each accident is the basic information required to analyze overall risk and to generate a risk profile for the subject of the analysis.

The PrRA risk profile includes three kinds of risk information:

Risk contributions. Determining the risk contribution of accidents provides a means to focus resources as narrowly as possible on accidents that are estimated to be the dominant risk contributors.

Risk matrix. This risk matrix illustrates the distribution of accidents according to their frequency of major, moderate, or minor severity categories. The matrix is a valuable risk communication tool and helps decision makers understand how many accidents fall into the various categories.

Expected number of accidents. This information shows the prediction of how many accidents will occur over the next year. The number is expressed as a range for each accident severity category. The range is a result of summing the upper and lower frequency scores selected for each accident severity category during the analysis.

Evaluate the benefit of risk reduction recommendations

Each recommendation from the preliminary risk analysis is designed to reduce the risk associated with the accidents discussed during the analysis. These recommendations may serve as preventive or mitigative safeguards, and they may apply to more than one accident.

This section provides a means to estimate the annual dollar savings due to the reduced risk realized by implementing recommendations. The dollar savings can be compared to the implementation cost of the recommendation in a benefit-cost analysis. Decision makers will use this benefit-cost analysis to decide if a recommendation should be implemented.

The benefit of implementing each PrRA recommendation is estimated by determining the potential reduction in frequency scores of accidents affected by the recommendations. This is accomplished by identifying the accidents associated with each recommendation and the accidents' frequency scores. For each frequency score, an estimate is made as to how the score will change if the recommendation is implemented.

The potential benefit gained from implementing a recommendation can be calculated by determining the change in the risk index numbers for the accidents affected by the recommendations.

The estimated range of dollar savings for each recommendation can be compared in several ways. The comparison allows decision makers to decide which recommendations should be implemented and in what order. In the graph, savings are represented over a five-year period by multiplying the savings calculated in the step on the previous page by 5. Any period of time can be chosen. The cost of implementing the recommendation can be included, as below, to assist decision makers in deciding whether to proceed with implementation or not.

Displaying all recommendations together allows comparison so that resources can be spent on the most effective ones first.

A.6. Alternative Preliminary Risk Analysis Method

To counter some of the general weaknesses of the PrRA, a more systematic technique can be applied. This technique is sometimes referred to as a coarse risk analysis and is a type of PrRA.

Deviation-based versus accident-based. The hierarchy developed for a conventional PrRA can be further broken down into individual deviations, or off-normal conditions that can result in an accident.

Instead of evaluating the accidents associated with a particular segment of the hierarchy, the deviations that cause accidents are themselves evaluated. The accidents initiated by the deviations can then be listed, as can the actual causes of the deviations and the safeguards in place to prevent them. This more systematic approach can help to reduce some of the uncertainty in the analysis.

More focused recommendations. The recommendations generated from this type of analysis are designed to prevent specific deviations from occurring and have more precise descriptions. These focused recommendations are also easier to evaluate from a benefit-cost perspective.

A.6.1. Limitations of this alternative technique

This technique is an excellent tool for understanding and comparing risk across an organization. However, it does have three main limitations:

Broad focus. This technique is designed to provide information to meet 60% to 90% of an organization's risk-based decision-making needs, hence the name coarse risk analysis. Even though this technique is more detailed than PrRA, there are some instances when the risk characterization data generated during a coarse risk analysis do not present the necessary detail to make some decisions. In these cases, a more detailed risk assessment tool should be used to reduce the uncertainty of the risk characterization and generate greater resolution of the data to make a good decision.

Time consuming. This technique systematically reviews credible deviations, investigates engineering and administrative controls to protect against the deviations, and generates recommendations for system improvements. The analysis process requires a substantial commitment of time both from the facilitator and from other subject matter experts, such as crew members, engineering, equipment vendors, etc.

Focuses on one-event causes of deviations. This technique focuses on identifying single failures that can result in accidents of interest. If the objective of the analysis is to identify all combinations of events that can lead to accidents of interest, more detailed techniques such as fault tree analysis should be used.

A.6.2. Steps for performing this alternative technique

The procedure for performing this analysis includes the following five steps.

1. **Determine the scope of the coarse risk analysis**. Determining the scope includes identifying the hazards, accidents, operations, and functions that will be analyzed.
2. **Screen low-risk operations, functions, and deviations.** Screening items streamlines the analysis by eliminating in-depth review of low-risk items.
3. **Analyze deviations.** Evaluating deviations is the fundamental activity in the coarse risk analysis. This involves identifying accidents, causes, and safeguards, and characterizing the risk associated with the deviation. Recommendations for reducing risk or uncertainty are also developed.
4. **Generate a risk profile.** The risk information generated from the coarse risk analysis can be sorted and reported in a variety of ways to aid in decision making.
5. **Evaluate** the benefit of risk reduction recommendations. Before a recommendation is implemented, the benefit or risk reduction gained from implementing the recommendation should be calculated and considered.

A.7. LOPA

A.7.1. Method Summary

LOPA is a form of simplified risk assessment that has been standardized to a set of rules. LOPA typically uses order-of-magnitude categories for cause frequency, consequence severity, and the likelihood of failure of independent protection layers (IPLs) to determine an approximation of risk of a scenario. LOPA is an analysis tool that typically builds on the information uncovered during a qualitative hazard evaluation.

Like many other hazard analysis methods, one primary purpose of LOPA is to determine if there are sufficient layers of defense against an accident scenario. Depending on the process complexity and potential severity of an accident, a scenario may require one or many layers of defense. Note that for a given scenario, only one layer must work successfully for the consequence to be prevented. However, since we know that no layer is perfect, we must layer sufficient defenses so that we are convinced the risk of the accident is tolerable.

LOPA provides a consistent basis for judging if there are sufficient IPLs to control the risk of an accident for a scenario. If the estimated risk of a scenario is not tolerable, a company may wish to add IPLs. LOPA does not suggest which IPLs to add, but it helps judge between alternatives for risk mitigation. LOPA is not a fully quantitative risk assessment approach, but is rather a simplified method for assessing the value of protection layers for a well-defined accident scenario. Figure A3 provides a visual representation of how a LOPA model is used to understand risk.

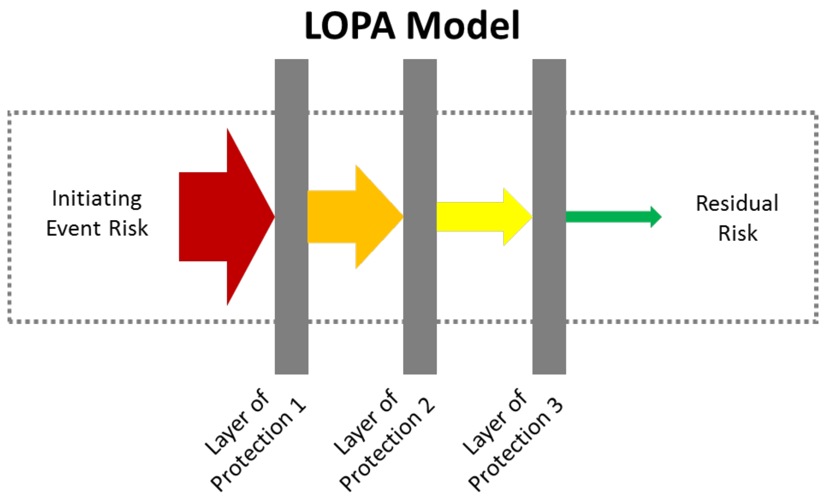


Figure A3. Visual Representation of LOPA Model

LOPA is one method that allows an analyst to evaluate reproducibly the risk of a selected accident scenario. The scenario is typically identified before LOPA during a qualitative hazard evaluation, such as a HAZOP or what-if analysis, management of change evaluation, or design review. LOPA provides an order-of-magnitude approximation of the risk of a scenario.

Once a cause-consequence pair is selected for analysis, the analysts can use LOPA to determine which safeguards meet the definition of IPLs, and then the analyst can estimate the residual risk of the scenario. The results can then be extended to make risk judgments and to help the analyst decide how much additional risk reduction may be required to reach a tolerable risk level. And while performing LOPA on one scenario, the analyst may uncover other scenarios or other issues.

Another approach to understanding LOPA is to view it relative to QRA. As shown in Figure A4, LOPA represents one path (typically the highest risk path) through an event tree.

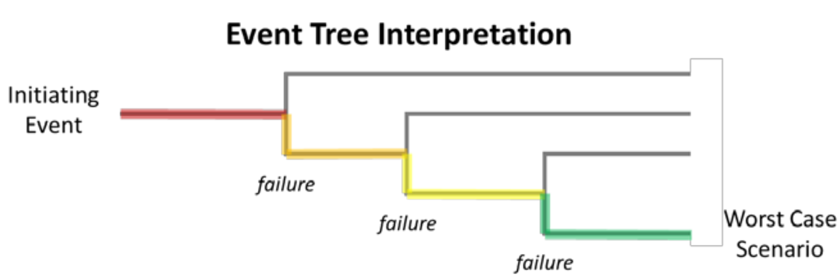


Figure A4. Event Tree Interpretation of LOPA

An event tree shows all the possible outcomes (consequences) of an initiating event. For LOPA, the analyst (or team) must limit each analysis to a single consequence, paired to a single cause (initiating event). In most applications of LOPA, the goal of the analyst is to choose the cause-consequence pair that represents the highest risk scenario of the many scenarios that may be similar to the one chosen. This is not always straightforward. In practice, the analyst who will apply LOPA will not have the benefit of picking a scenario from a fully developed event tree. Instead the data used for LOPA typically begins with a statement from a qualitative hazard review team. The goal is to choose scenarios that the analyst believes will represent the significant risk scenarios. As mentioned earlier, LOPA is a method that falls between qualitative and quantitative methods and should be used when the analyst decides it is the most efficient tool for judging risk.

LOPA is typically used following a qualitative hazard evaluation (e.g., HAZOP), where LOPA uses the scenarios developed by qualitative hazard review teams. However, “typically” means just that – LOPA can also be used to analyze scenarios that originate from any source, including design option analysis and incident investigations. LOPA is primarily used when a hazard evaluation team (or other entity) believes (1) the scenario is too complex for the team to make a reasonable risk judgment using purely qualitative information or (2) the consequences are very severe. The hazard evaluation team may judge the scenario as “too complex” if it (1) does not understand the initiating event well enough or (2) does not understand the sequence of events well enough.

LOPA can also be used as a screen prior to more rigorous, quantitative methods for assessing risk. When used as a screen, each scenario above a specified consequence or risk level will first go through a LOPA, and then certain scenarios will be targeted for higher level of risk assessment. The decision to proceed to quantitative risk assessment is typically based on the risk level determined by LOPA or based on the opinion of the LOPA analyst (i.e., the scenario is too critical to rely on LOPA for risk assessment). In general, we believe that if the analyst or team can make a reasonable risk decision, using purely qualitative methods, LOPA may be overkill. However, for complex situations, judging sufficiency of IPLs can be much more efficient using LOPA results than when using only qualitative information. When using only a qualitative hazard review, these decisions can quickly digress into a shouting match. LOPA should not be used as a replacement for quantitative analysis. If complex human behavior models or equipment failure models are needed to understand the risk of a scenario, then quantitative analysis is more appropriate.

LOPA

- Conservative analysis of risk of loss from a single threat
- Moderate complexity methodology
- Produces quantitative output
- Requires SME input
- Identifies independent layers of protection surrounding the possibility of loss

A.7.2. Method Limitations

Nearly all limitations of LOPA are self-imposed to result in a method that is much less complex than QRA. In summary, LOPA has the following limitations:

LOPA is only valid for making risk comparisons of scenarios analyzed by LOPA when LOPA is applied uniformly across an organization (i.e., based on comparison to risk tolerance criteria or to the risk of other scenarios determined by LOPA). Numbers generated by a LOPA calculation are not precise values of the risk of a scenario. This is also a limitation of QRA.

LOPA is a simplified approach and should not be applied to all scenarios. LOPA is overkill for some risk-based decisions and is overly simplified for other decisions.

Using LOPA to reach a risk-based decision requires more time than using qualitative methods such as HAZOP and what-if. This extra time should be offset by the value of the better decision that can be reached compared to using only qualitative methods for moderately complex scenarios. For simple decisions, the value of LOPA may be minimal. For complex scenarios and decisions, LOPA may actually save time compared to using only qualitative methods because it focuses on decision making.

LOPA is not intended to be a scenario identification tool. It is highly dependent on the methods used (including qualitative hazard review methods) to identify (1) the potential loss scenarios for analysis using LOPA and (2) a starting list of causes and safeguards. However, the rigorous thought process of LOPA frequently clarifies ill-defined scenarios generated in qualitative hazard reviews.

Differences in the expression of risk tolerance criteria and in implementation of LOPA between companies mean the results cannot be compared directly across the industry (this is true of QRA techniques as well).

A.7.3. Procedure

Like all analytical methods, LOPA has rules that must be followed. And like other methods, LOPA can be divided into various discrete steps. To capture the full power of LOPA, an organization will need to adopt a consistent approach to LOPA and set criteria for when to use LOPA and who is qualified to use LOPA. The basic LOPA steps are:

Step 1: Identify the accident scenario. LOPA is developed for one scenario at a time. The scenario can come from other analyses (such as qualitative analyses) but the scenario describes a single cause-consequence pair.

Step 2: Identify the initiating event of the scenario and determine the initiating event frequency (events per year). The initiating event must lead to the consequence (given failure of the safeguards). The frequency must account for background aspects of the scenario, such as the frequency of the mode of operation for which the scenario is valid. Some companies provide guidance on estimating the frequency to help build consistency in LOPA results.

Step 3: Identify the consequence (including the impact) and estimate the value that represents the magnitude of the consequence. Some companies stop at the magnitude of a release (or of energy), which implies but does not explicitly state the impact on people, the environment, and the production system. Other companies will more explicitly estimate the impact on people, the environment, and production by accounting for the likelihood of harm of a specific scenario, for instance by also accounting for the probability of operators being in harm's way during a release scenario.

Step 4: Identify the IPLs and estimate the probability of failure on-demand of each IPL. Recall that LOPA is an acronym for "layer of protection analysis." Some accident scenarios will require only one IPL, while other accident scenarios may require many IPLs or IPLs of very low probability of failure on demand, depending on the risk of the scenario. Identifying the safeguards that meet the requirements of IPLs is the heart of LOPA.

Step 5: Mathematically combine the consequence, initiating event, and IPL data to estimate the risk of the scenario. Other factors may be included during the calculation, depending on the definition of consequence (or impact event). Approaches include arithmetic formulas and graphical methods.

Step 6: Use the results for reaching a risk decision concerning the scenario. The most common uses of the results of LOPA include comparing the risk of a scenario to a company's tolerable risk criteria (or related targets).

A.8. Bowtie

A.8.1. Method Summary

Bowtie analyses have grown in popularity in the offshore petroleum production industry. They are accepted as barrier analyses by Norway's PSA and the UK's HSE. Often, the bowtie analysis is used to encode a complex operating environment in a consistent, understandable format. Bowtie analyses are most often qualitative and are more for identification of the barriers in place than for predicting failure rates or probabilities. A typical Bowtie analysis centers around a loss event (called "top event"). The process of constructing a Bowtie analysis helps practitioners identify the causal factors leading the top event as well as the consequences following from that top event. Then the barriers and mitigation measures that are in place to prevent such negative developments are identified and added to the analysis.

Although Bowtie analyses center around a single top event, when multiple top events are being studied, a set of bowties (one for each top event) can be constructed where threats, barriers, and consequences overlap between each model. This can help users of the bowties to understand the interconnectedness of the systems.

Appendix B.2 contains an example of a Bowtie analysis in the offshore context.

Bowtie Analysis

- Systematically encodes information related to a single top event
- Accommodates multiple threats, barriers, mitigation measures, and consequences
- Moderate complexity
- Produces qualitative results
- Construction requires in-depth understanding of system

A.8.2. Method Limitations

Non quantitative output. Despite the level of effort required to identify the logic in a bowtie analysis, the method is not typically used to identify quantitative results.

A.8.3. Procedure

Even though Bowtie analyses are most often qualitative, they are generally moderately complex to construct and require in-depth knowledge of the system being modeled. The analysis may require at least significant amounts of research and most often will include consultation with SMEs. Individuals involved in the daily operations of the system being modeled are invaluable resources in the construction of the analysis. Not only do such individuals understand the system design, but they also come equipped with special knowledge of how protocols and operations are carried out in reality. The steps for performing a Bowtie Analysis are as follows:

1. Identify Top Event
2. Identify Threats (Causes)
3. Identify Barriers
4. Identify Consequences
5. Identify Mitigations

Identify Top Event

The central component of a Bowtie analysis is the top event. The top event is defined as the unleashing of a hazard. An example hazard might be the presence of hydrocarbons or a high-pressure oil reservoir. In the first case, the top event might be the leaking of hydrocarbons into the ocean or hydrocarbon ignition leading to a major fire. A high-pressure oil reservoir might have a blowout as a top event.

When identifying the top event, the timing of the selected event is essential. The top event should be the incident or accident that occurs after all attempted prevention measures (barriers) are applied but before any mitigation measures take place. Otherwise, the identification of barriers or mitigation measures may be unnecessarily limited. For example, if the top event is that a hydrocarbon fire causes a fatality, the analysis may capture barriers that should have prevented the fatality, but may overlook mitigation measures against other kinds of loss. It is important that the “knot” of the Bowtie be centered.

Identify Threats (Causes)

Once the top event is established, possible threats that can lead to the top event must be identified. A threat is anything that, in the absence of barriers, could lead to the top event. Threats should be defined broadly enough that there is not an exhausting number of unique threats but narrowly enough that specific barriers can be assigned to each threat without having to be unnecessarily genericized.

Identify Barriers

The next step is to identify barriers. Barriers stand in the way of threats developing into the top event. One barrier may apply to a variety of threats or may only apply to one threat. A barrier might be a piece of equipment, a protocol, or a human. In any case, the description of the barrier should be specific enough that it provides tangible understanding of how the system would be different if the barrier were removed. Instead of “drilling engineer” for example, the barrier description should indicate the action that the drilling engineer would need to take to neutralize the threat.

Identify Consequences

Most often, a major top event will lead to multiple kinds of losses. There may be lost production, equipment damage, pollution, injuries, fatalities, etc.. As in the case of threats, consequences should be identified generically enough that there are not too many consequence types, and specifically enough that the mitigation measures can be appropriately mapped to them. Overly generic consequences will be difficult to identify mitigation measures for. In identifying consequences, the worst case outcomes should be considered. While these outcomes are not necessarily expected to be manifest, it should be understood that unmitigated consequences can be large.

Identify Mitigations

Mitigation measures stand between the top event and the consequence. Mitigation measures, when successful, help to reduce the likelihood of and/or severity of consequences.

A.9. FTA

A.9.1. Method Summary

A fault tree is a detailed logic model (using Boolean logic) describing the combinations of failures that can produce a specific system failure of interest. FTA is most often used as a system-level analysis technique to generate:

- Qualitative descriptions of potential problems (combinations of events causing specific problems of interest)
- Quantitative estimates of failure frequencies/likelihoods and relative importance of various failure sequences/contributing events
- Lists of recommendations for reducing risks
- Quantitative evaluations of recommendation effectiveness
- A fault tree analysis is generally applicable for almost every type of analysis application, but most effectively used to address the fundamental causes of specific system failures dominated by relatively complex combinations of events. FTA is performed by a skilled analyst who uses input from system experts and conducts field inspections to generate a comprehensive review of a system. This review helps to ensure that appropriate safeguards are in place to prevent system failures.

FTA

- Model describes possible sub-failures that lead to the overall failure of a system
- Complex modeling process
- Produces quantitative information
- Examines multiple failures
- Provides easily understood graphical models

A.9.2. Method Limitations

Fault Tree Analysis is an art as well as a science. Although highly technical, there is no formula for developing an effective FTA. Always, the developer must decide where to define boundaries and how to define relationships between model elements.

It requires a skilled analyst. Unlike some models, which can be successfully build by a beginner, a FTA will likely require an experienced practitioner to ensure that the model is sufficiently detailed but also pragmatic.

It is narrowly focused on only one particular type of problem within a system. FTA is insufficient for models describing loss events or complex interactions between equipment or components. For this reason, FTA is usually developed as a supporting model for ETA.

A.9.3. Procedure for Fault Tree Analysis

The procedure for performing a FTA consists of the following eight steps:

1. **Define the system of interest.** Specify and clearly define the boundaries and initial conditions of the system for which failure information is needed.
2. **Define the TOP event for the analysis.** Specify the problem of interest that the analysis will address (a specific quality problem, shutdown, safety issue, etc.).
3. **Define the treetop structure.** Determine the events/conditions (i.e., intermediate events) that most directly lead to the TOP event.
4. **Explore each branch in successive levels of detail**. Determine the events/conditions that most directly lead to each intermediate event. Repeat the process at each successive level of the tree until the fault tree model is complete.
5. **Solve the fault tree for the combinations of events contributing to the** loss. Examine the fault tree model to identify all the possible combinations of events/conditions that can cause the TOP event of interest. A combination of events/conditions that is sufficient and necessary to cause the TOP event is called a minimal cut set.
6. **Identify important dependent failure potentials and adjust the model appropriately.** Study the fault tree model and the list of minimal cut sets to identify potentially important dependencies among events (i.e., single occurrences that may cause multiple events/conditions to occur/exist at the same time). This step is qualitative common cause failure analysis.
7. **Perform quantitative analysis (if necessary).** Use statistical characterizations about failure and repair of specific events/conditions in the fault tree model to predict future performance for the system.
8. **Use the results in decision making.** Use the results of the analysis to identify the most significant vulnerabilities in the system and to make effective recommendations for reducing the risks associated with those vulnerabilities.

Define the system of interest

Intended functions. Because FTAs focus on how a system can fail to perform a specific function, clearly defining that function is an important first step.

Physical boundaries. Few systems operate in isolation. Most are connected to (or at least interact with) other systems. Clearly defining the boundaries of a system (especially boundaries with support systems such as electric power and compressed air) is important to avoid (1) overlooking key elements of a system at interfaces and (2) penalizing a system by associating other equipment with the subject of the study.

Analytical boundaries. Conceptually, FTAs can include all of the possible events/conditions that can produce a specific type of system problem. However, including all possible contributors is not practical. Many analyses define analytical boundaries that (1) limit the level of resolution of analysis (e.g., deciding not to analyze in detail all electrical distribution system problems) and (2) explicitly exclude certain types of events/conditions from the analysis (e.g., ignoring sabotage).

Initial conditions. The initial state of a system (including equipment that is assumed to be out of service initially) affects the combinations of additional events necessary to produce a specific system problem. For example, if a protective interlock has been temporarily removed from service, the risk of certain types of problems occurring will be greater and, thus, will affect how the fault tree is drawn/evaluated.

Define the TOP event for the analysis

Because FTA is a focused analysis tool, begin with a clear statement of the problem of interest. The top event should have two elements:

- **Subject** - the entire system or a specific element (subsystem, component, etc.) of the system
- **Specific functional failure or condition** - A precise description of a problem or condition of interest, defined as narrowly as possible

Define the treetop structure

The next step in a FTA is to determine the events/conditions (i.e., intermediate events) that most directly lead to the TOP event. This step involves two key elements: logic structure and most direct contributors

- **Logic structure -** the logical relationship between the TOP event and the underlying contributors
- **Most direct contributors -** the intermediate events/conditions (generally in broad categories at the upper levels of fault trees) that most directly lead to the TOP event

Like TOP events, intermediate events/conditions should also have a subject and a specific functional failure or condition. In the building of a fault tree, top events are tied to intermediate events through logic gates (discussed in section A.9.4). In effect, the logic gates portray how the occurrence of intermediate events leads up to the top event. Figure B4 and Figure B5 in appendix B.3 provide examples of completed FTAs with intermediate events leading up to the top event.

The treetop structure should represent a baby step in the analysis of the TOP event. This step of development should take a small, logical step toward the underlying contributors to the problem of interest, but should avoid the urge to jump to details that are best left to subsequent levels of the tree. Jumping too quickly to the details often causes analysts to overlook entire branches of development that may be important to the final results. Each level of development should represent the universe of possible contributors (excluding those specifically set outside the scope of the study).

Explore each branch in successive levels of detail
The analysis process continues at successive levels of detail until the model is complete. The model is complete when each branch of the fault tree has been pursued to the lowest level of resolution deemed necessary by the analyst. Each branch should end with a basic event or an undeveloped event.

Knowing where to stop an analysis is the key to avoid overworking problems. The level of detail in an analysis should be barely adequate (i.e., just enough) to provide the insights necessary for decision making. It is better to begin with a limited level of analysis and add to the analysis in selected areas than to initially overanalyze the problem.

Solve the fault tree for the combinations of events contributing to the loss
A minimal cut set is a collection of basic events (and undeveloped events) that are necessary and sufficient to cause the TOP event. For example, a dead battery and three faulty spark plugs is a cut set for the car not starting, but not a minimal cut set. A dead battery alone is a minimal cut set. Three faulty spark plugs alone are another minimal cut set.

For any fault tree, there are generally many minimal cut sets that can cause the TOP event. Some minimal cut sets may be as simple as 1 event; others may be much more complex, involving 3, 5, 10, or even more events.

Procedure

1. Name all gates and basic/undeveloped events
2. Beginning with the TOP event, expand each gate into its inputs as follows: OR Gates: Replace the gate with the sum of its inputs
3. Continue the expansion until only basic events remain in the equation (i.e., all intermediate event gates have been replaced)
4. Simplify the equation (eliminate any parentheses) by using the associative law of multiplication
5. Simplify the equation by:
    a. Eliminating repeated basic events in cut sets
    b. Eliminating supersets (i.e., cut sets that contain other complete cut sets)

Generally speaking, minimal cut sets with the fewest number of events are more likely (and thus, more important) than longer cut sets. Also, events that appear in shorter cut sets and/or more cut sets are generally more important than other events. This type of qualitative judgment about cut set and event importance is called structural importance.

Identify important dependent failure potentials and adjust models appropriately
Identifying dependent failures is a process of examining sequences of events to detect how multiple failures/errors can occur from the same underlying root causes, thereby defeating multiple layers of protection simultaneously.

Whenever significant dependent failures are detected, the fault tree model can be modified to explicitly include the common cause failure. To do this, a branch modeled as multiple independent failures can be replaced with two branches: the original multiple independent failures OR an alternate branch with one common cause failure. Alternatively, the minimal cut sets that contain events with dependencies can be repeated with the separate independent events replaced by a single common cause event.

Perform quantitative analysis (if necessary)
Quantifying the risks associated with potential combinations of human errors and/or component failures provides more precise results than qualitative analysis alone. Quantifying the risks of potential failure combinations has many benefits:

- Overall levels of risk can be judged against risk acceptance guidelines (if such guidelines exist)
- Risk-based prioritization of potential failure combinations provides a highly cost-effective way to allocate resources (design, maintenance, etc.) to best manage the most significant risks
- Risk reductions can be estimated to help justify the costs of recommendations generated during the analysis

Use the results in decision making
Judge acceptability. Decide whether the estimated performance for the system meets an established goal or requirement (generally only possible if quantitative analysis is performed).

Identify improvement opportunities. Identify the elements of the system that are most likely to contribute to future problems (i.e., the most important events).

Make recommendations for improvements. Develop specific suggestions for improving future system performance, including any of the following:

- Equipment modifications
- Procedural changes
- Administrative policy changes (such as planned maintenance tasks, personnel training, etc.)

Justify allocation of resources for improvements. Estimate how implementation of expensive and/or controversial recommendations for improvement will affect future performance. Compare the benefits of these improvements to the total life cycle costs of implementing each recommendation (generally only possible if quantitative analysis is performed).

A.9.4. Fault Tree Elements

Below are the symbols used to construct a fault tree:

Top event and intermediate events - The rectangle is used to represent the TOP event and any intermediate fault events in a fault tree.

Basic events - The circle is used to represent basic events in a fault tree. It is the lowest level of resolution in the fault tree.

Undeveloped events - The diamond is used to represent human errors and events that are not further developed in the fault tree.

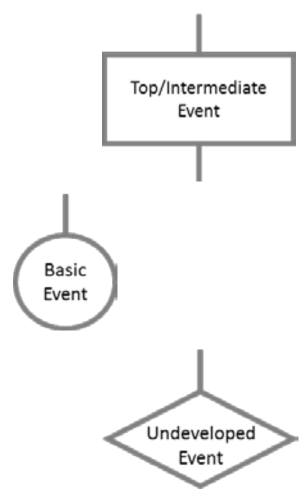


Figure A5. Fault Tree Analysis Event Symbols

AND gates - The event in the rectangle is the output event of the AND gate below the rectangle. The output event associated with this gate exists only if all of the input events exist simultaneously.

Use an AND gate whenever:

- Multiple elements must be present for an event to occur or a situation to exist
- Multiple pathways (flow, pressure, current, etc.) must all be in specific states (all open, all closed, or some combination) for an event to occur or a situation to exist
- Redundant equipment items must all fail for an event to occur or a situation to exist
- Safeguards must fail for an event to occur or a situation to exist

OR gates - The event in the rectangle is the output event of the OR gate below the rectangle. The output event associated with this gate exists if at least one of the input events exists.

Use an OR gate whenever:

- Any one of several elements can cause an event to occur or a situation to exist
- Failure of any one part of a system causes it to fail
- Any one of several pathways (flow, pressure, current, etc.) in a specific state (open or closed) allows an event to occur or a situation to exist

Inhibit gates - The event in the rectangle is the output event of the INHIBIT gate below the rectangle. This gate is a special case of the AND gate. The output event associated with this gate exists only if the input event exists and if the qualifying condition (the inhibiting condition shown in the oval) is satisfied.

An INHIBIT gate is simply a special form of an AND gate. The INHIBIT gate event occurs when the condition is TRUE and an input event occurs.

Transfer symbols - Transfer symbols are used to indicate that the fault tree continues on a different page.

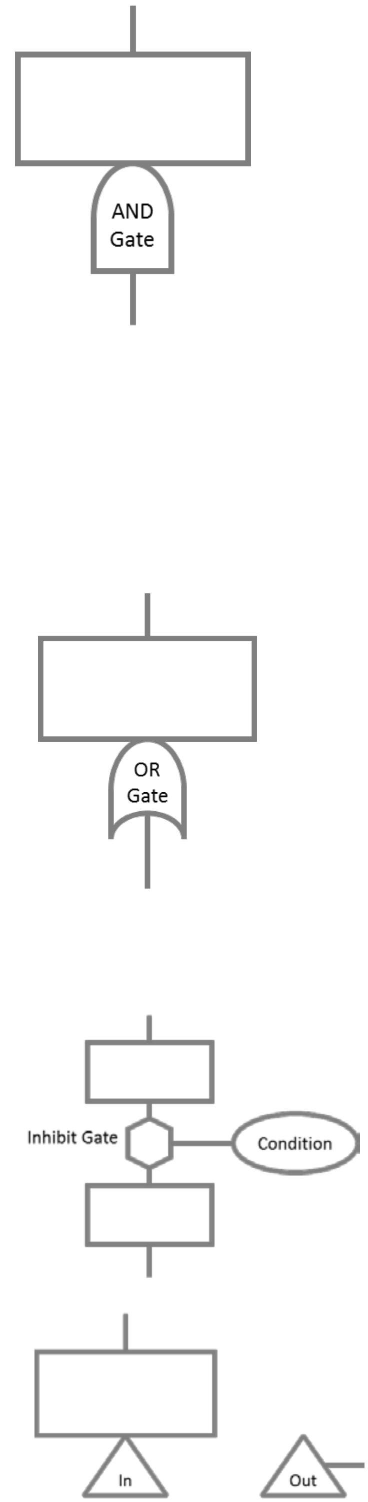


Figure A6. Fault Tree Analysis Gates and Transfer Symbols

A.10. ETA

A.10.1.Method Summary

ETA is an inductive analysis that graphically models (using decision trees) the possible outcomes of an initiating event capable of producing a consequence of interest. An ETA can identify a range of potential outcomes for a specific initiating event, and allows an analyst to account for timing, dependence, and domino effects that are cumbersome to model in fault trees.

A skilled analyst develops the event tree by inductively reasoning chronologically forward from an initiating event through intermediate safeguards and conditions to the ultimate consequences. The analyst then reviews the model results with knowledgeable operations and emergency response personnel so they can suggest corrective actions when the model reveals significant weaknesses.

ETA

- Model of failure/mitigation sequence following an initiating event
- Accounts for multiple possible outcomes
- Complex methodology
- Requires skilled analysts and SME input
- Accounts for timing of events
- Models domino effects that are cumbersome to model in fault trees

A.10.2.Event Tree Terminology

The following terms are commonly used in an ETA:

Initiating event - the occurrence of some failure with the potential to produce an undesired consequence

Line of assurance - A protective system or human action that may respond to the initiating event

Branch point - Graphical illustration of (usually) two potential outcomes when a line of assurance is challenged; physical phenomena (e.g., ignition) may also be represented as branch points

Accident sequence or scenario - one specific pathway through the event tree from the initiating event to an undesired consequence

A.10.3.Method Limitations

Limited to one initiating event. Unlike a Bowtie analysis which centers on the top event and can accommodate a whole array of threats, ETA only accommodates one initiating event.

Requires special treatment to account for system dependencies.

Requires skilled and experienced analyst(s). First time practitioners of ETA or individuals who have limited understanding of the risks being studied will have a difficult time implementing an ETA.

A.10.4.Procedure for ETA

The procedure for performing an ETA consists of the following seven steps:

1. **Define the system or operation of interest.** Specify and clearly define the boundaries of the system or operation for which ETAs will be performed.
2. **Identify the initiating events of interest.** Conduct a screening level hazard analysis to identify the events of interest or categories of events (e.g., leaks, fires, explosions, toxic releases) that the analysis will address.
3. **Identify lines of assurance and physical phenomena.** Identify the various safeguards (lines of assurance) that will help mitigate the consequences of the initiating event. Also identify physical phenomena (e.g., ignition, meteorological conditions) that will affect the outcome of the initiating event.
4. **Define accident scenarios.** For each initiating event, define the various accident scenarios that can occur.
5. **Analyze accident sequence outcomes.** For each outcome of the event tree (accident sequence), determine the appropriate frequency and consequence that characterizes the specific outcome.
6. **Summarize results.** ETA can generate numerous accident sequences that must be evaluated in the overall analysis. Summarizing the results in a separate table or chart will help organize the data for evaluation.
7. **Use the results in decision making.** Evaluate the recommendations from the analysis and the benefits they are intended to achieve (e.g., improved safety/environmental performance, cost savings, and/or additional output). Determine implementation criteria and plans. The results of the event tree may also provide the basis for decisions to perform additional analysis on a selected subset of accident scenarios.

Define the system or operation of interest

Intended functions. Because ETAs focus on how initiating events can progress to more severe events due to subsequent failures of various safeguards (lines of assurance), clearly defining the function of safeguards is an important first step in identifying their effectiveness as a line of assurance.

Physical boundaries. Few systems operate in isolation. Most are connected to (or at least interact with) other systems. Clearly defining the boundaries (especially boundaries with support systems such as electric power and compressed air) is important to avoid (1) overlooking key elements of a system at interfaces and (2) penalizing a system by associating other equipment with the subject of the study.

Analytical boundaries. Conceptually, ETAs can include all of the possible events/conditions that can contribute to initiating events or provide some level of protection (line of assurance) against consequences of interest. However, including all possible contributors is not practical. Many analyses define analytical boundaries that (1) limit the level of resolution of analysis (e.g., deciding not to analyze in detail all electrical distribution system problems when studying a compressed air system) and (2) explicitly exclude certain types of events/conditions from the analysis (e.g., sabotage).

Initial conditions. The initial state of a system (including equipment that is assumed to be out of service initially) affects the combinations of events necessary to produce subsequent problems. For example, if a protective interlock has been temporarily removed from service, the risk of certain types of problems occurring will be greater and will, therefore, affect how the event tree is drawn/evaluated.

Identify lines of assurance and physical phenomena

Functional responses. Identify the various safeguards (lines of assurance) that will help mitigate the consequences of the initiating event. These are the detection and mitigation systems that are designed to respond to the initiating events. They consist of (1) engineered systems (e.g., alarms, interlocks, automatic valves) and (2) administrative/personnel systems (e.g., fire brigade, emergency response, human detection [sight, sound, smell]).

Physical phenomena. Physical phenomena, sometimes referred to as phenomenological events, will also influence the eventual outcome of an initiating event. For example, if a release of a flammable liquid occurs, there may be engineered safeguards (lines of assurance) to isolate the leak; however, if the leak is not isolated, there are different physical responses (e.g., immediate ignition, delayed ignition, dispersion characteristics) that will affect the ultimate outcome of the release. These physical responses are also modeled as branch points on the event trees.

Group initiating events. For analysis with multiple initiating events to be analyzed (i.e., requiring multiple event trees to be drawn), the effort of drawing the many event trees can be simplified if the events are grouped according to the lines of assurance. This will allow the same event tree logic (i.e., the same lines of assurance with the same failure/success) to be repeated for different events of interest. Or, if the lines of assurance will respond in an identical manner to various events, then the frequencies of the individual events can usually be summed to arrive at a representative frequency for all events of that type.

Define accident scenarios

At this point the analyst has sufficient information to begin developing the event trees. As noted earlier, one of the strengths of the ETA technique is its ability to model the timing and interaction of the various systems that respond to the initiating event. To adequately account for these interactions, the analyst must (1) determine the logical progression of the accident as it moves through the various lines of assurance, (2) identify dependencies between the lines of assurance, (3) account for conditional responses of one system, given the action of the previous system, and (4) construct the event tree to illustrate these issues.

Determine accident progression. Certainly all failures do not result in catastrophic health and safety consequences. Similarly, not every safety feature is called upon to respond to every event that occurs. There is a logical progression of an accident sequence that moves forward from the time the initiating event occurs. As the accident progresses and becomes more severe, different systems respond in different ways. Understanding the progression and timing of system and physical responses is essential to developing the correct logic in the event tree. For example, if a fire ignites by spontaneous combustion in a waste receptacle, the initial response would be for personnel to extinguish the fire with handheld extinguishers, if personnel were present and there were extinguishers available. The full fire protection system and/or the response of the fire team would not be called upon unless the severity of the accident increased.

Identify system dependencies. Few systems operate in isolation. Most are connected to (or at least interact with) other machines and processes. These interactions, or dependencies, will influence (degrade) the level of protection offered by redundant systems that share certain equipment.

Understand conditional responses. Event trees illustrate conditional probabilities. That is, the probability of success or failure of a line of assurance is conditional on the success or failure of the lines of assurance that precede it. For example, the probability of failure for the second hydraulic brake system is 1.0 (i.e., it is failed) given that the reason for the failure of the first system is that the hydraulic fluid supply is contaminated.

Construct event tree logic. Event tree construction consists of the following steps:

1. List the initiating event first on the left side of the tree.
2. List the lines of assurance and physical phenomena across the top of the tree in the chronological order in which they will affect the accident progression.
3. Identify success (usually displayed in the upward branch) and failure (downward branch) of each line of assurance at each branch point considering that:
    a. some branch points can have more than two outcomes and will be displayed with the appropriate number of branches
    b. some branch points will have only one outcome (i.e., there is a straight line through that line of assurance); this will occur when the conditional probability is 1.0 (i.e., the line of assurance does not affect the outcome because of some preceding success or failure of another line of assurance)

Analyze accident sequence outcomes

After the event tree is constructed as described in the previous step, the analyst will have a clear picture of the progression of the accident to each of the various outcomes. Each outcome is uniquely represented by a frequency and consequence and can be evaluated either qualitatively or quantitatively.

Frequency

In general, the accident sequence outcomes in an event tree, if constructed as described in the previous step, will be ordered from high frequency and low consequence to low frequency and high consequence. Each outcome has a frequency associated with that outcome. Qualitatively, the frequency of the outcome may be determined simply by observing the number of independent lines of assurance that would have to fail in order for a specific outcome to occur. For example, a catastrophic equipment failure would only occur if an operator failed to recognize the onset of the problem and three independent safety systems failed to automatically detect and shut down the equipment. At the other extreme, if only one safeguard (line of assurance) is provided for protection of a particular event, then that event may be considered anticipated or likely to occur.

Quantitative evaluation of accident frequencies is accomplished by multiplying together the initiating event frequency and all of the probabilities from the various branch points.

Consequence

Each outcome has a consequence associated with that outcome. Qualitatively, the consequences of the outcome may be determined simply by observing the number of independent lines of assurance that failed (or succeeded) and how far the accident progressed in order for a specific sequence to occur. For example, if personnel failed to recognize the onset of the problem and three independent safety systems failed to automatically detect and shut down the equipment, then a catastrophic equipment failure may be expected to result. At the other extreme, if personnel detected the problem, and quickly shut down the machine, then the consequences would be expected to be less severe.

Quantitative evaluation of consequences involves various consequence modeling and effects modeling that are applicable to the type of accident scenarios being analyzed. For example, an event tree may describe the accident sequence for a medium-sized release of a toxic material that occurs during cargo unloading. The release continues for 1 hour before operators isolate the release. Quantitative evaluation of the consequences of this scenario would involve release rate modeling (to determine the rate at which material escapes from the equipment), atmospheric dispersion modeling (to estimate the downwind concentrations of the toxic material), and demographic data around the facility (to estimate the number of people exposed to the specific concentrations calculated by the dispersion models).

Summarize results

ETA can generate numerous accident sequences that must be evaluated in the overall analysis. The evaluated frequency and severity of each sequence makes up the results of the analysis. Depending on the number of scenarios identified, appropriate result summaries might range from a simple table or chart to a more complex F-N curve.

The F-N curve plots the cumulative frequencies of events causing N or more impacts, with the number of impacts (N) shown on the horizontal axis. With the F-N curve, you can easily see the expected frequency of outcomes that could result in greater than a specific outcome of interest (e.g., capital dollars lost, number of spills). To generate the F-N curve, the accident scenarios are sorted from the highest to the lowest consequence. Then the frequency data are accumulated for each scenario. The x axis plots the consequence, and the y axis plots the cumulative frequency.

Use the results in decision making

Evaluate the recommendations from the analysis and the benefits they are intended to achieve (e.g., improved safety/environmental performance, and/ or cost savings). Determine implementation criteria and plans. The results of the event tree may also provide the basis for decisions to perform additional analysis on a selected subset of accident scenarios.

Identify improvement opportunities. Identify the elements that are most likely to contribute to future problems (i.e., the items with the largest percentage contributions to the pertinent factors of merit).

Make recommendations for improvements. Develop specific suggestions for improving future performance, including any of the following:

- Equipment modifications
- Procedural changes
- Administrative policy changes (such as planned maintenance tasks, personnel training, etc.)

Justify allocation of resources for improvements. Estimate how implementation of expensive and/or controversial recommendations for improvement will affect future reliability performance. Compare the economic benefits of these improvements to the total life cycle costs of implementing each recommendation.

B. Sample Frameworks

Within the adaptive resolution concept, it is important that the structure selected for the simple risk modeling can inform the more sophisticated modeling techniques needed to develop a complete understanding for higher risk issues. Section B.1 focuses on potential structures for a simple PrRA model to serve as the key foundation of an adaptive resolution risk program. Sections B.2 and B.3 provide examples of moderate and complex models, respectively, to provide supplemental detail once the simple model foundation is established.

B.1. Simple Model Foundation

This section explores the dimensions of analysis that might be available for the performance of a PrRA. The PrRA process generates high-level results. Typically, it is oriented around various loss scenarios mapped to multiple types of consequence. Several steps make up the PrRA process:

- Establish model scope
- Screen out low risks
- Analyze historical incidents and data
- Generate a risk profile
- Inform decisions through change analysis

B.1.1. Model Scope

The number and types of scenarios used within a PrRA determine the model scope. These scenarios may be generated through unstructured brainstorming or more systematically. The analysis team would suggest that scenarios be systematically structured and oriented around types of incidents and the context in which these incidents occur. Careful selection of broad incident categories and contexts enables the formation of a mutually exclusive and collectively exhaustive set of scenarios, acknowledging all significant risks within BSEE's jurisdiction. Other objectives in scenario selection include:

- Utilizing available objective data to the greatest extent
- Selecting an array of scenarios with distinguishable risk levels
- Maintaining a process that is easily supplemented by moderate and complex models
- Minimizing the number of scenarios

The first step of determining model scope is to identify significant incident types. BSEE's annual report includes a number of incident types, including fatalities, injuries, loss of well control, fires/explosions, collisions, spills, lifting accidents, gas or H_2S releases, and musters for evacuation. These statistics are used as performance indicators and do not distinguish between incident types and incident consequences. In a PrRA, this distinction must be made clear. The analysis team identifies the following possible incident types:

- Blowout
- Fire/Explosion
- Collision
- Lifting Accident
- Personnel Mishap

International incident reporting sometimes includes incident types not explicitly mentioned in BSEE's annual report[24]:

- Helicopter Mishap
- Loss of Power
- Diving Accident
- Hydrocarbon Leak

None of these categories reflect either root causes or consequence. To overcome the difficulty that one event can include multiple incident categories, it is assumed that only the first-occurring event is applicable. If a blowout causes a leak that catches on fire, this incident would be classified as a blowout. If a fire destroys drilling equipment, leading to loss of well control and a blowout, this would be classified as a fire. That said, the Personnel Mishap category is intended as a catch-all category for other events leading to loss (e.g., slips, trips, falls).

The second step is to determine informative dimensions for describing the context of various incidents. After review of BSEE data related to incidents, platforms, and geological conditions, the evaluation team has identified a number of possible dimensions for defining the scope of a PrRA process. Table B1 lists examples of various categories within each dimension.

Table B1. Potential PrRA Context Dimensions

Operating Mode	Region	Water Depth	Reservoir Temperature	Reservoir Pressure	Facility Type	Complex Size	BOP Type
Production Drilling Well Intervention Abandonment	Gulf Pacific Atlantic Arctic	Shallow Moderate Deep	Low Medium High	Low Medium High	Fixed Semi-sub. Drillship Jack-up TLP	Minor Major	Topside Subsea

There are other possible dimensions to choose from, but for a high-level PrRA, only a few should be selected to establish the analytic structure. For example, the framework could evaluate risk for unique combinations of region, operating mode, and reservoir pressure. With only these three dimensions, the number of permutations with four regions, four operating modes, and three reservoir pressure categories, yields 48 unique context categories.

Additionally, further analysis may find, for example, that significant risk correlation between the region and reservoir pressure may make these dimensions redundant. In such a case, removing the reservoir pressure dimension would reduce the number of unique context categories to 16. Sixteen context categories combined with five incident types would produce 80 scenarios for analysis and review.

[24] See also Appendix 0 for a comparison of performance indicators used by foreign offshore regulators.

Finally, for each scenario, there might exist several different consequences. For regulatory agencies with a wide variety of missions, even a dozen consequence types might be possible. BSEE will most likely be concerned with a smaller set of consequence types such as:

- Death and Injury
- Environmental
- Direct Economic Loss (such as property damage)
- Secondary Economic Loss

In the Macondo accident, each of these losses was experienced. 11 workers were killed, others were injured, the owner/operator suffered direct economic losses, secondary economic losses were experienced to a variety of industries in the GoM, and the spilled oil effected environment.

B.1.2. Risk Screening

If any scenario is not plausible or considered to be a negligible risk, it can be excluded from further analysis in this step. The number of excluded scenarios depends on the scenario structure.

B.1.3. Scenario Analysis

Once the structure of the analysis is developed, available data are needed to inform preliminary estimates of the risk level for each scenario. For each historical incidents, losses are quantified according to the consequences identified in the model framework. At this point, it may be necessary to develop a consequence equivalence matrix. This matrix serves as a “Rosetta Stone” specific to BSEE risk priorities. Table B2, shows a generic matrix illustrating equivalent losses for each impact type:

Table B2. Example Consequence Equivalence Matrix

Severity Level	Death & Injury	Direct Economic Loss	Secondary Economic Loss	Environmental Damage
1	No deaths; 1 life-threatening injury	$10,000 to $300,000 in damage/loss	No Impact On Economy	Environmental nuisance; 1.5 bbls to 15 bbls of oil spilled
2	No deaths; 1-5 life-threatening injuries	$300,000 to $3 million in damage/loss	Minimal impact on local impact	Environmental threat; 15 bbls to 150 bbls of oil spilled
3	1 death and other life-threatening injuries	$3 million to $30 million in damage/loss	Minor impact on local economy	Species endangered; 150 bbls to 1,500 bbls of oil spilled
4	2 to 5 deaths and other life-threatening injuries	$30 million to $300 million in damage/loss	Moderate impact on local economy; Minor impact on regional economy	Local species collapse; 1,500 bbls to 15,000 bbls of oil spilled
…	…	…	…	…

After incidents are classified by loss type and severity, the PrRA process tallies up the frequency of losses by scenario, consequence type, and loss severity. Table B3 shows a sample historical loss frequency summary for the Fire/Explosion on a Drilling Facility in the GoM scenario. The complete dataset would include all scenarios.

Table B3. Sample Historical Loss Frequency Data Format

Accident Type	Region	Operating Mode	Consequence	Class 1	Class 2	Class 3	…
Fire/ Explosion	GOM	Drilling	Death & Injury			Decade	…
			Direct Economic Loss		Monthly	Quarterly	…
			Secondary Economic Loss			Annually	…
			Environmental Damage		Quarterly	Annually	…
…	…	…	…	…	…	…	…

Often, a frequency categorization scheme, such as defined in Table B4, will be used to keep the analysis simple.

Table B4. Incident Frequency Categorization Scheme

Frequency Category	Description	Value
Continuously	> 550 events per year	730
Daily	210 to 550 events per year	365
Weekly	32 to 210 events per year	52
Monthly	8 to 32 events per year	12
Quarterly	3 to 8 events per year	4
Annually	1 to 3 events per year	1
Decade	1 event every 2 to 20 years	0.1
Half-century	1 event every 20 to 70 years	0.02
Century	1 event every 70 to 180 years	0.01
Millennium	1 event every 180 or more years	0.001

Frequency categories also make it easier when SMEs review the data and modify it to reflect what they expect to be the future risk profile. Instead of getting bogged down in slight trends or deviations in overly-precise incident trends, SMEs can focus on the high-level, major changes that will affect the risk profile. Several important factors make modifications to the historical data important to the success of a PrRA process. These include:

- Underreported incidents
- Data inaccuracy because of low-event frequency
- Expected changes in the risk profile

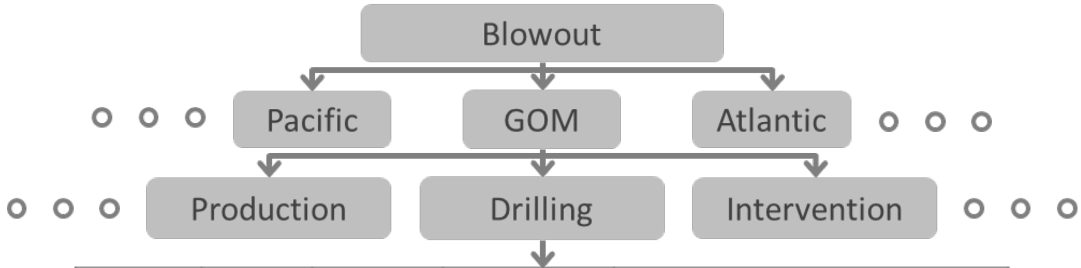
Table B5 shows how SMEs might review historical reported data and adjust it to reflect their understanding of the current risk level.

Table B5. Comparison of Historical Reported Incident Frequency and Adjusted Frequency

Fire/Explosion - GOM - Drilling - Environmental Damage			
Severity	**Historically Reported Frequency**	**Adjusted Frequency**	**Reason for Adjustment**
1		Quarterly	Expected underreporting of very small spills
2	Quarterly	Annually	Expected decrease in small spills
3	Annually	Annually	
4		Decade	Inaccurate data because of low event-frequency.
5		Decade	Inaccurate data because of low event-frequency.
…	…	…	…

B.1.4. Risk Profile Generation

After processing the data, the risk profile can be generated. For each scenario and impact, the notional risk value for each risk class is multiplied by the frequency of an incident in that class taking place. Summing each of the products of risk level and frequency generates a RIN. Using the example accident context dimensions, Figure B1 demonstrates how the PrRA model computes each unique accident, region, operating mode, and consequence type. Once these RIN's are computed, the profile can be easily analyzed for decision-making purposes. For example: All RINs can be summed by Operating Mode to get a sense of which Operating Mode contributes the most risk overall and might require further analysis.



Accident Type	Region	Operating Mode	Consequence	Severity Categories		
				Class 1	Class 2	Class 3
Blowout	GOM	Drilling	Death & Injury			Decade
			Direct Economic Loss		Quarterly	Biannually
			Secondary Economic Loss			Decade
			Environmental Damage	Monthly	Quarterly	Annually

Consequence	0.165	1.65	16.5
Frequency	12	4	1
Risk (RIN)	**1.98**	**6.6**	**16.5**

Environmental Damage Risk of Drilling Blowout in the GOM = 25.08 RIN

Figure B1. Risk Profile Generation

B.1.5. Decision Making

PrRA supports decisions in three primary ways. First, it provides an overall structure for thinking about risks within BSEE jurisdiction. Second, it allows for a standardized measure of risk so that different incident contexts can be identified for further study or regulation. Finally, PrRA can be easily modified to support change analysis.

For example, if the decision is whether to focus oversight resources toward drilling facilities or toward production facilities, a modified risk profile can be generated for each case. SMEs would be used to determine changes in loss frequencies brought about by each of the oversight options. Whichever modified risk profile generated the lower RIN overall would then be selected as the oversight option with more effective risk reduction.

B.2. Moderate Model for Deeper Understanding

Medium and high risks identified through PrRA may warrant further analysis through a moderately complex LOPA or Bowtie analysis. Unlike PrRA which takes a holistic view of risk, Bowtie analysis focuses on a single risk event. It studies the causes of the event and the barriers in place to prevent such an event. Additionally, a Bowtie analysis will review consequences of the event and the measures in place to mitigate such consequences.

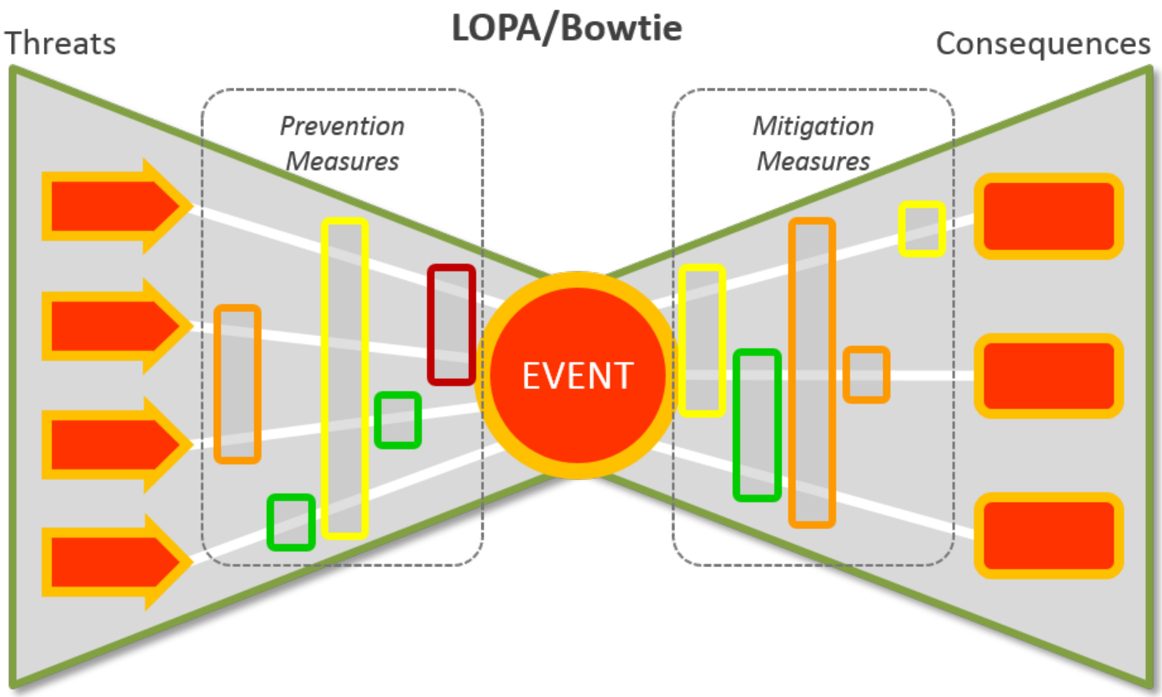


Figure B2. Notional Bowtie Model

Figure B2 illustrates all of the major components of the Bowtie model. The primary goal of the Bowtie structure is to facilitate understanding complex systems and safety features in a linear, easy-to-understand way. One can be constructed through careful consideration of a progression of questions:

1. What initiating events (threats) can lead to the event of interest?
2. What systems, protocols, or equipment (barriers) are in place to keep initiating events from producing the event of interest?
3. What consequences follow the event of interest?
4. What systems, protocols, or equipment (mitigation) are in place to reduce potential consequences after the event has already occurred?

Often, the answers to these questions require input from SMEs and other individual's in the field.

Table B6 and Table B7 present the results of a Bowtie analysis for a blowout event. Under the Adaptive Resolution framework, an analysis like this one might be used if the PrRA had identified blowouts on drilling facilities in the GOM to be a medium or high risk. The Bowtie analysis would then support a more in-depth understanding of the risk. Table B6 summarizes the threats and barriers identified. Table B7 summarizes consequences and mitigation measures. Each "X" in the tables represents where a barrier or mitigation applies to the given threat or consequence. This analysis can be extended to quantify the overall risk of blowout, and might inform inspections and regulations about what measures make up industry best practice.

Table B6. Bowtie Threats and Related Barriers

Barriers	Threats: Mud Out Of Specification	Mud Circulation Pumps Failure	High Lower Riser Angle	Swabbing/Surging While Tripping Drill String Or Tools In The Hole	Tripping/Casing Operations Failures	Cementing Operations	Drilling Into Shallow Gas Pockets	Drilling Into Unexpected High Pressure Formation
Annulus Flowline Monitoring		X		X	X			
BHA Design Criteria			X	X				
Diverter							X	X
Drilling Fluids Operators Trained And Licensed	X		X	X	X			
Drilling Operators Trained And Licensed To Recognize Influx Into The Wellbore And To Contain The Well	X	X	X	X	X		X	X
Drill Pipe Float Valve							X	
Drilling Program Design	X		X	X	X	X	X	X
Kelly Cock Prevents Flow Up Drill String	X	X	X	X				
Kill Well And Circulate Out Kick	X	X	X	X	X	X		
Minimize Tripping Speed				X	X			
Mud Logging	X		X					
Mud Pumps Design Criteria		X						
Mud Pumps Maintenance And Inspection Program		X						
Mud Pumps Redundancy		X						
Pithand Monitoring The Circulation Of Fluid From The Well's Flow Line To The Shakers	X		X					
Reserve Mud	X		X					
Shut-In Drill Pipe Pressure	X	X	X	X	X	X		
Stab-In Safety Valve To Prevent Flow Up Drill String				X	X			
Trip Tank Level Monitoring And Pit Volume Totalizer (PVT) System		X		X	X			
Use Of Appropriate Formulation To Minimize Required Setting Time						X		

Table B7. Bowtie Consequences & Mitigation Measures

Mitigation Measures	Consequences: Personnel Injury	Consequences: Discharge to the Environment	Consequences: Financial Loss	Consequences: Reputation Impact
Active Fire Protection	X			
Insurance			X	
Emergency Communication System	X			
Emergency Plan for Oil Discharge		X		
Emergency Response Plan and Procedures	X			
Individual Emergency Plan for Oil Pollution		X		
Lifeboats/Life Rafts and Survival Equipment	X			
Multiple Escape Routes and Safe Muster Areas	X			
Passive Fire Protection	X			
Pull-off location (Emergency Disconnect)	X	X	X	
Crisis Management Plan				X

Figure B3 shows a selection of these threats, barriers, consequences and mitigations in the format of a Bowtie diagram.

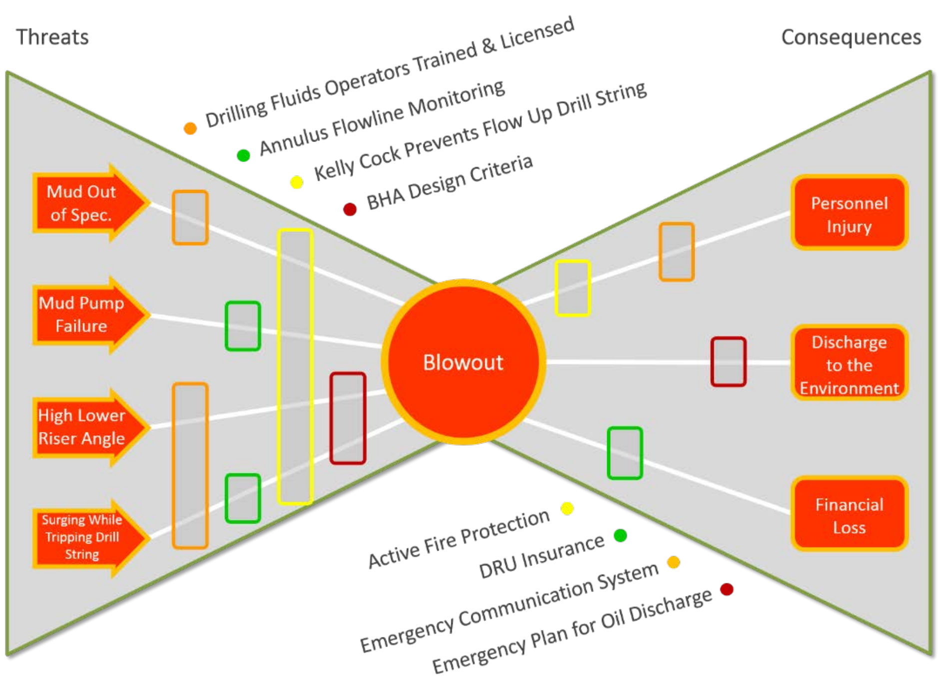


Figure B3. Example Bowtie Diagram

Once a Bowtie framework has been developed, the frequency of a given accident can be estimated if the approximate initiating event rates and the barrier reliabilities are known. Similarly, estimates of consequence can be made if the severity of the consequence can be determined given the consequence types and the effectiveness of the mitigation measures is understood. Combining the frequency and consequence elements, a higher-confidence estimate of risk for the given scenario can be made to supplement the rough estimate produced using PrRA.

B.3. Complex Model for In-Depth Understanding

To further improve risk understanding to a level of detail beyond LOPA/Bowtie, FTA can be used to determine the likelihood of a given barrier failing. Figure B4 and Figure B5 present example fault trees.

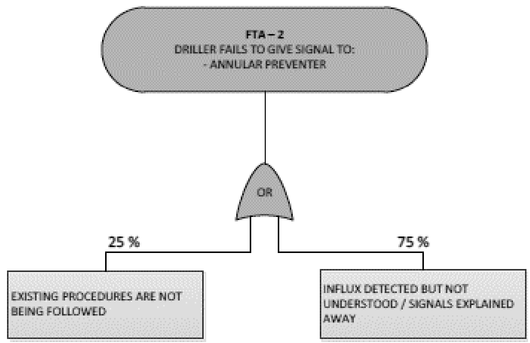


Figure B4. Simple Fault Tree

The highest level of model complexity recommended for the Adaptive Resolution approach is an ETA/FTA model. In this model, the event tree stems from the initiating event rather than centering on the ultimate incident type. From the initiating event, all other occurrences follow, and multiple incident types may be possible. The event tree will also often rely on fault trees for calculation of failure rates of specific components or equipment subsystems. ETA/FTA logic is also especially useful for Monte Carlo simulation, allowing a more robust set of important metrics than the Bowtie provides.

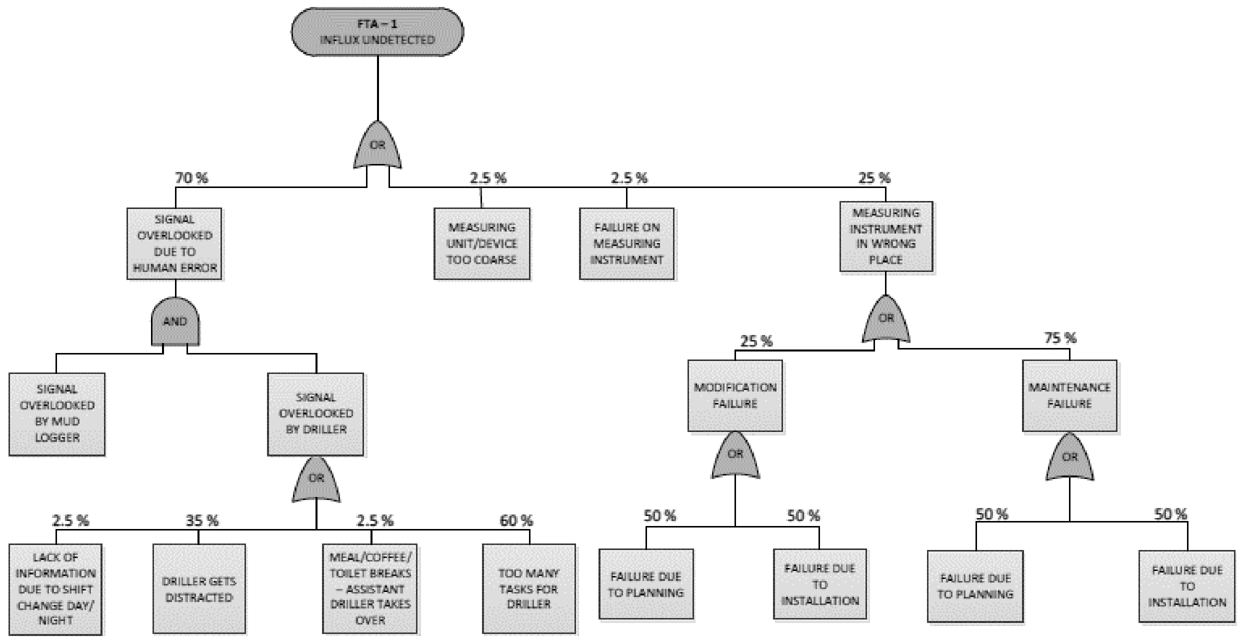


Figure B5. Complex Fault Tree

Figure B6 depicts a portion of a very detailed fault tree related to the events and consequences following a well kick, a precursor to a blowout.

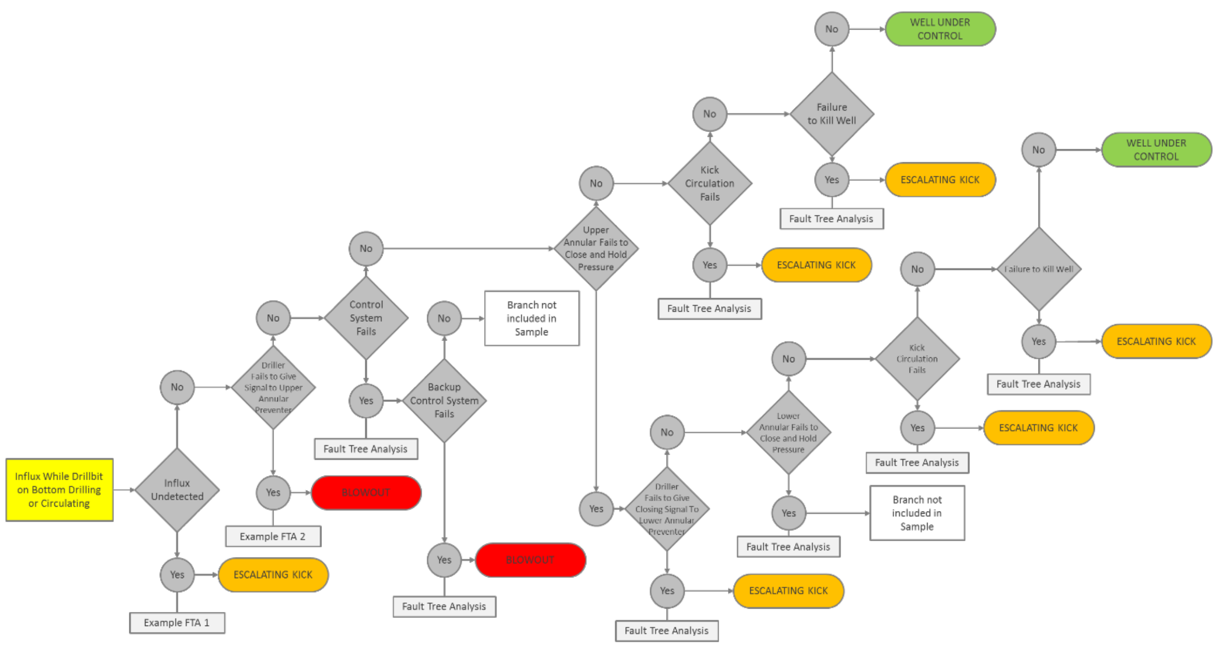


Figure B6. Example Complex Event Tree

C. Review of Key Performance Indicators

Table C1 presents a comparison of the key performance indicators used by several large offshore regulatory agencies. The bulleted items under select items provide detail on how the data is reported for each metric. Table C2 provides the source documents in which the KPIs were identified.

Table C1. KPI Source Documents

Regulator	Report Referenced
BSEE	2014 Annual Report
PSA	Trends in Risk Level in the Petroleum Activity (RNNP) 2014
HSE	Annual Offshore Statistics & Regulatory Activity Report 2013/2014
NOPSEMA	Annual Offshore Performance Report (2014)

Table C2. Comparison of Key Performance Indicators

BSEE	PSA	HSE	NOPSEMA
Regulatory Performance KPIs			
Inspections • By Region • Well Operations • Production • Pipelines • Meters • Environmental • Other **Spill Preparedness Audits** • By Region • Tabletop **Government Initiated Unannounced Exercise (GIUE)** • Deployment GIUE • Spill Management • Team Audits • Equipment • Deployment Audits • Equipment Verification of Capabilities **Incidents of Noncompliance** • Completion • Crane • Drilling • Electrical • General • Hydrogen Sulfide • Measurement & Site Security • Pipelines • Pollution • Production • Well Workover/ Abandonment • USCG-related **Fines Paid** • By Operator		**Investigations Completed** **Safety Cases Assessed** **Installations Inspected** **Improvement Notices** **Prohibition Notices**	**Investigations** • High Risk Category Incidents • Complaints • Environmental Incidents • Assessments • Occupational Health And Safety • Well Integrity - Well Activities • Environmental Management • Petroleum Safety Zones • Regulatory Advice Sought By Other Agencies • By Outcome (In Progress, Accepted, Recalled, Rejected, Returned) • By Time Spend (NOPSEMA, Industry) **Inspections** **Enforcements** • Improvement Notices • Advice/Warnings • Prohibitions • Prosecution Briefs o Design o Hazardous Substance o Noise Exposure o Risk Assessment And Procedure Controls o Systems, Policies, Administrative Controls o Late Notification Of Dangerous Occurrence o Interference With Incident Site o Maintenance Management o Undertaking Activity Contrary To Environment Plan o Safety Case Noncompliance o Reporting

BSEE	PSA	HSE	NOPSEMA
Safety Culture KPIs			
	HSE Climate **Perceived Accident Risk** **Working Environment** • Noise o By Job Position o By Facility Class o With/without Hearing Protection • Chemicals o By Hazard Class o By Facility Type o Exposure Reduction Plan Performance • Ergonomics o By Job Position o By Facility Type **Leisure** **Health & Sickness Absence**		**Complaints** • Management Issues • Culture/General Safety **Issues** • Work **Procedures/Methods/ Practices** • Competency/Staffing • Equipment • Safety-Critical Equipment • Work Environment - Noise, Heat, Pollution • Services/Galley/ Accommodation • Reporting Investigations/Incidents, Remedial Actions • Fatigue/Shifts/Rosters • Bullying/Intimidation • Cyclone Evacuations • HSR Matters/Safety Committees • General Environmental Matters/Pollution • Stakeholder Consultation Activities • Timing Of Petroleum Activities
Risk Exposure KPIs			
Production Volume • By Type (Oil, Gas) • By Region (Alaska, Gulf of Mexico, Pacific) **# of Operators** **# of Platforms** **# of Wells Drilled** **# of Drilling Rigs** **Pipeline Length**	**Production** • # of Facilities • # of Wells • Man-hours • Production Volume • Pipeline Length **Exploration** • # of MODUs • # of Exploration Wells • Man-hours **Helicopter** • Transport Service Hours • Shuttle Traffic Hours		**Man-hours** • Fixed • Mobile **Operators** **Titleholders** **Facilities** • Pipeline • # of Production **Platforms** • # of FPSO • # of Vessels • # of MODUs **Activities** • Operations • Other Petroleum Activity • Drilling • Seismic • Other Surveys • Construction
Near Miss KPIs			
	Serious Near Misses • Incidents Related To Helideck Movement • Turbulence During Rig Approach • Static Discharge • ATM Related Incidents		

<table>
<tr><th>BSEE</th><th>PSA</th><th>HSE</th><th>NOPSEMA</th></tr>
<tr><td></td><td>• Operational Incidents
• Technical Incidents
• Helideck Factors
• Violations Of Procedures
• Persons In Restricted Section
• Obstruction
• Turbulence
• Equipment Malfunction
• Wrong/Missing Information
• Wrong Position/Rig
ATM Aspects
Bird Strikes
Ship on Collision Course
Drifting Object</td><td></td><td></td></tr>
<tr><td colspan="4">Root Cause KPIs</td></tr>
<tr><td>Available from BSEE Investigations
• Procedures
• Training
• Quality Control
• Communication
• Management System
• Human Engineering
• Work Direction
• Design
• Equipment/Parts Defects
• Preventive/Predictive Maintenance
• Management Systems
• Tolerable Failure</td><td></td><td></td><td>• Procedures
• Training
• Quality Control
• Communications
• Management Systems
• Human Engineering
• Work Direction
• Design
• Equipment/Parts Defects
• Preventive/Predictive Maintenance
• Management Systems
• Tolerable Failure</td></tr>
<tr><td colspan="4">Barrier Testing KPIs</td></tr>
<tr><td></td><td>Well Integrity
• One Barrier Failed, One Degraded
• One Barrier Failed, One In Tact
• One Barrier Degraded, One In Tact
• Both Barriers in Tact
Safety Systems
• Fire Detection
• Gas Detection
• Riser ESDV
• Wing & Master Valve
• DHSV
• BDV
• PSV
• BOP
• Deluge Valve
• Fire Pump Start
Marine Systems
• Watertight Doors
• Ballast Valves
• Jack-Up Height
Maintenance Backlog (Hours)</td><td></td><td></td></tr>
</table>

BSEE	PSA	HSE	NOPSEMA
	• Preventive/Corrective • HES/Other Equipment		
Incident KPIs			
Fire/Explosion • Catastrophic • Major • Minor • Incidental **Collision** • Major • Minor **Evacuation** • Loss of Well Control • Surface • Surface Equipment • Diverter • Underground • Spills • Crude/Refined Petroleum • Chemicals • Mixture **Releases** **Lifting**	**Fire/Explosion** **Other Areas (Combustible Liquid)** **Falling Object** • External • Design • Human • Technical • Drilling/Crane/Process/ General **Diving Accident** **Man Overboard** **Evacuation** • Precautionary • Emergency **Loss Of Well Control** • Exploration • Drilling • Serious Shallow Gas • Shallow Gas • High Risk • Regular **Falling Object** **Collision** **Damage To Structure/Anchoring/Positioning** • Mobile Unit • NUI • Complex • FPU • Fixed Production **Damage To Subsea Production Equipment/Pipeline Systems/Diving Equipment Caused By Fishing Gear** **Helicopter Crash/Emergency Landing Near Facility** **Full Loss Of Power** **Ignited Hydrocarbon Leak** **Leak From Subsea Production Facility/ Pipeline/ Riser/ Wellstream/ Pipeline/**	**Dangerous Occurrences** • Major • Significant • Minor • By type (Hydrocarbon release, well incidents, pipelines, other)	**Accidents** **Dangerous Occurrences** **Reportable Incidents** **Recordable Incidents** **Environmental** • Hydrocarbon Release • Chemical Release • Fauna Incident • Drilling Fluid/Mud Release • Other • Breach Of Procedural Control • Gas Release • Solid Waste Discharge/Dropped Object • Nonconformance With Planned Discharge • Other • Spill To Deck - No Discharge To Marine Environment • Other Planned Liquid Discharge • Non Hydrocarbon Air Emissions • Equipment Not Functioning • Seabed/Benthic Damage • Injury Or Death To Fauna **Occupational Health & Safety** • Fire/Explosion • Collision • Potential Injuries • Investigation Necessary • Unplanned • Damage To Safety Critical Equipment **Hydrocarbon Releases** • Design • Procedures • Preventive Maintenance • Management Systems • Human Engineering • Tolerable Failure • Equipment Parts/Defects **Gas Releases**

BSEE	PSA	HSE	NOPSEMA
	Loading Hose **Damage To Risers/Pipelines Within Safety Zone** • NUI • Complex • FPU • Fixed Production **Non-Ignited Hydrocarbon Leak** • >10 Kg/S • 1-10 Kg/S • 0.1 To 1 Kg/Sec • Oil/Gas **H2s Emissions**		
Casualty KPIs			
Fatalities • Operation (Helicopter, Diving Related, Construction Fall, Personnel Transfer, Man Overboard, Electrocution, Support Vessel - Anchor) **Injuries** • Major • Minor • Other **Lost Time Accidents** • >3 days • 1 to 3 days • <1 day	**Personal Injury** • Serious • Production vs. Mobile Facility **Work-related illness**	**Fatalities** **Injuries** • Major • Over 7 days • Over 3 days • By Type (Fracture, Sprain, Laceration, Contusion, Dislocation, Other) • By Part (Upper Limb, Lower Limb, Torso, Head, Other) • By Action (Handling/Lifting/Carrying, Slip/Trip/Fall, Struck by Object, Fall from Height, Other) • By Activity (Maintenance/construction, deck operations, drilling, management, production, diving) **Diseases** • Chickenpox • Decompression illness • Hand-arm vibration • Mumps • Occupational dermatitis	**Fatalities** **Injuries** • Major Injuries • Alternative Duties Injuries • Medical Treatment Injuries • Total recordable cases • By Facility Type • By Mechanism (Moving Object, Hitting Object, Body Stress, Slip/Trip/Fall, Chemicals, Heat/Electricity/Environmental, Other) • By Agency (Non-powered equipment, Machinery/Fixed Plant, Chemicals, Powered Equipment, Mobile Plant/Transport, Environmental, Other)

D. ALARP Application

The UK's HSE pioneered the use of ALARP in regulation. Their application of ALARP is essentially universal; every dutyholder must perform risk assessments to identify safety risks and actions needed to minimize those risks. Dutyholders are everyone who exposes someone to a risk, from owner/operators of offshore rigs to people renting out a church hall for choir practice. Many dutyholders face minimal risks and can demonstrate that their risk level is generally acceptable and so need only qualitative risk assessments (e.g. the church hall operator). Offshore petroleum production does not fall in the generally acceptable risk range. Every operator of a high hazard site or offshore platform must submit a Safety Case demonstrating that they have identified all major accident hazards and that the associated risks are ALARP. While very few agencies worldwide are using ALARP principles on a broad scale, a number of countries are using ALARP specifically in the regulation of the offshore petroleum production environment.

The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) is the agency in charge of regulating offshore petroleum production in Australia. Since the passing of the Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations in 2009, NOPSEMA has been managing an ALARP-based regulatory regime. Prior to 2009, NOPSEMA's predecessor, the National Offshore Petroleum Safety Authority (NOPSA), had maintained similar requirements. In several Australian states, ALARP principles are also applied in the process of establishing land use for high-risk facilities such as refineries and other plants.

In New Zealand, the WorkSafe NZ program enforces Regulation 26(2) of the Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations passed in 2014. This regulation requires new facilities to submit safety cases prior to beginning operations.

The Danish Energy Authority (DEA) maintains similar ALARP provisions for the offshore facilities that it manages.

The ALARP approach removes significant responsibility from the regulator to determine how operators achieve required safety thresholds. However, different regulators can still tailor their approach in order to reflect societal differences.

Figure D1 presents a comparison of the legally-defined individual risk tolerances of various regions around the world. For the majority of these regions, the tolerances have been set for the purposes of land use planning, not for ALARP applications in petroleum production regulation. Still, the graph shows how risk tolerance is specific to the regulator and varies by region.

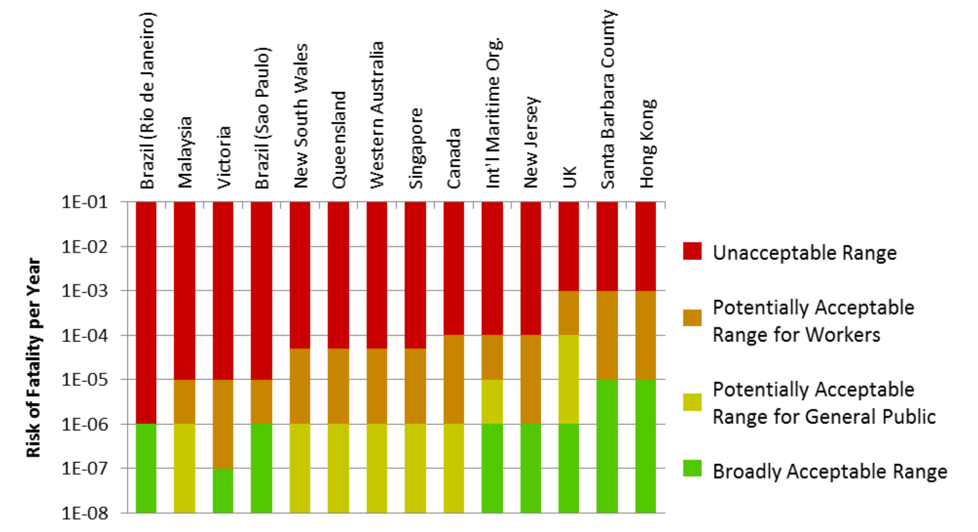


Figure D1. Comparison of Risk Tolerance Thresholds

E. Additional Program Overview Diagrams

E.1. USCG RBI

The purpose of the proposed RBI risk management program is to support the USCG's Office of Commercial Vessel Compliance in the development of a risk-based approach to vessel inspections. The program's objectives are to:

- Better focus inspection efforts on high risk systems and sub-systems on the vessels
- Characterize the risk of discrepancies found during the inspection
- Estimate the relative risk reduction of the inspection outcomes
- Support risk status trending of inspected vessels and fleets

Over the last decade, USCG decision makers have found it increasingly necessary to justify the allocation of resources to various activities. This has been driven largely by the constrained budget climate as well as limited USCG resources to allocate among the competing demands across the USCG's many missions. The lack of an effective and systematic means to measure the effectiveness of vessel inspection activities also makes this justification increasingly difficult.

The proposed RBI program would provide a full suite of risk-informed decision support tools to help identify inspection focus areas, characterize the criticality of the discrepancies found during an inspection, and recommending enforcement actions based on an understanding of the risk of the discrepancy. Table E provides summary information about the program.

Table E1. USCG RBI: Program Attributes

Attribute	Description
Origin Date	**Proposed**
Analytical Complexity	**Simple**
Program Maturity	**N/A –** The program has been proposed but is not yet in development
Frequency of Use	**Continuous** – Supports various USCG inspection activities
Risk Management Support to Mission Scope	**Narrow** – RBI is focused on the inspection activities within USCG's Marine Safety mission (1 of 11 missions)
Key Context Factors	• **Industry Scale:** High – the USCG is responsible for thousands of commercial vessels • **Political Factors:** Because the USCG's mission set is so broad, there are numerous political factors that affect their operations and regulatory philosophy. • **Agency Maturity:** High – agency was founded in 1790
Government Level of Effort	**Low** – Simple risk analysis is performed by government representatives
Point of Contact	**CAPT Kyle McAvoy,** Kyle.P.McAvoy@uscg.mil

Figure E1 provides an overview of the proposed USCG RBI risk management program by identifying the key inputs to the analysis process, the models used, the outputs of the models, and the decisions informed by the analysis. Table E2 provides details about each element presented in the figure

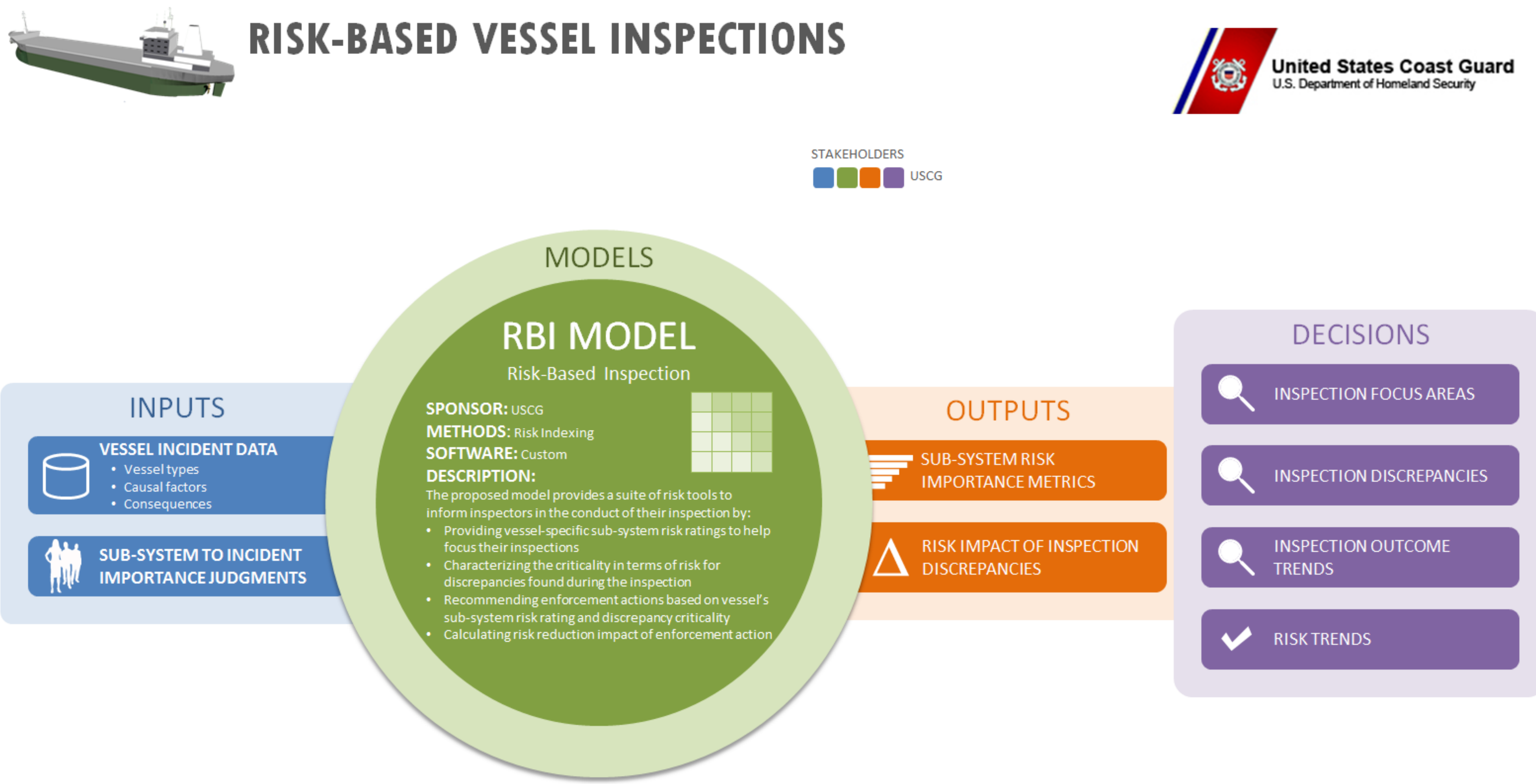


Figure E1. USCG RBI: Program Overview

Table E2. USCG RBI: Program Details

USCG RBI: Program Details	
INPUTS	
Name	**Description**
Government	
Vessel Incident Data	**Type:** Database **Source:** USCG Incident Investigators **Description:** Maritime accident data are gathered by USCG incident investigators for reportable incidents. These incident reports contained detailed information on the accident, including: location, root cause information, types of vessels/facilities involved, fatalities, injuries, property damage, and spill size. This information is stored in the USCG's MISLE database.
Sub-system to Incident Importance Judgments	**Type:** SMEs **Source:** Experience **Description:** Collective judgment of group of SMEs about the risk sensitivity and risk contribution of failure of vessel sub-systems to an array of various maritime accidents.
Industry	
No industry inputs associated with this program.	
MODELS	
Name	**Description**
Government	
RBI Model	This proposed model will provide a suite of risk tools and metrics to inform inspectors in the conduct of their inspection. • **Methods:** RBI employs a simple risk indexing methodology which guides SMEs through a systematic process to collect their judgments about the risk sensitivity and risk contribution of failure of vessel sub-systems to an array of various maritime accidents. • **Software:** Prototype will be developed in a customized MS Excel spreadsheet.
Industry	
No industry models associated with this program.	
OUTPUTS	
Name	**Description**
Government	
Sub-System Risk Importance Metrics	Process generates two importance metrics for each vessel sub-system: • **Risk Sensitivity**, which represents: given that the sub-system fails, what is the likelihood that the maritime accident will occur. Sub-systems with high risk sensitivity will lead directly to an incident (e.g., there is limited redundancy in the function provided by the sub-system and the sub-system is difficult to recover in a timely manner). • **Risk Contribution**, which represents: given an accident occurs, what is the likelihood that the failure of the particular sub-system was a contributor.
Risk Impact of Inspection Discrepancies	Characterization of the risk of the vessel sub-system with and without a discrepancy
Industry	
No industry outputs associated with this program.	

USCG RBI: Program Details	
DECISIONS	
Name	**Description**
Government	
Inspection Focus Areas	Inspectors would use importance metrics to help focus their inspection efforts on high risk vessel systems and sub-systems
Inspection Discrepancies	Inspectors would use risk impact metrics related to discrepancies they found in vessel sub-systems to help inform their enforcement actions.
Inspection Outcome Trends	Inspection program office would aggregate the risk impact of inspection outcomes (e.g., enforcement) to characterize the impact of the program.
Risk Trends	Inspection program office would trend vessel and fleet risk scores over time to characterize the impact of the program.
Industry	
No industry decisions informed by this program.	

E.2. MSHA Risk and Readiness Assessment

To effectively assess risk and readiness across the coal mining industry, MSHA developed several separate risk and readiness assessment models to help prevent major mine emergencies and improve emergency response. The purpose of the MSHA Risk and Readiness Assessment program is to supply the mining industry with a proactive toolset for underground coal mine operators to self-assess:

- The risks associated with their mines and methods to prevent major mine emergencies
- Their preparedness to respond to an emergency
- The readiness of their rescue teams, responsible persons, and the Government and industry to execute their emergency plans

Table E3 provides summary information about the program.

Table E3. MSHA Risk and Readiness Assessment: Program Attributes

Attribute	Description
Origin Date	**2013**
Analytical Complexity	**Simple**
Program Maturity	**Medium**
Frequency of Use	**On Demand** – Voluntary program by mine operators
Risk Management Support to Mission Scope	**Broad** – Addresses a wide array risk, readiness, and preparedness issues for coal mines
Key Context Factors	• **Industry Scale:** Large – MSHA is responsible for regulating thousands of active mining operations • **Political Factors:** MSHA's mission is to prevent death, disease, and injury from mining and to promote safe and healthful workplaces for the Nation's miners. • **Agency Maturity:** High – MSHA was founded in 1977
Government Level of Effort	**None** – All analysis is performed by industry.
Point of Contact	**Dr. Jeffery Kravitz,** Kravitz.Jeffery@dol.gov

Figure E2 provides an overview of the proposed MSHA Risk and Readiness Assessment program by identifying the key inputs to the analysis process, the models used, the outputs of the models, and the decisions informed by the analysis. Table E4 provides details about each element presented in the figure.

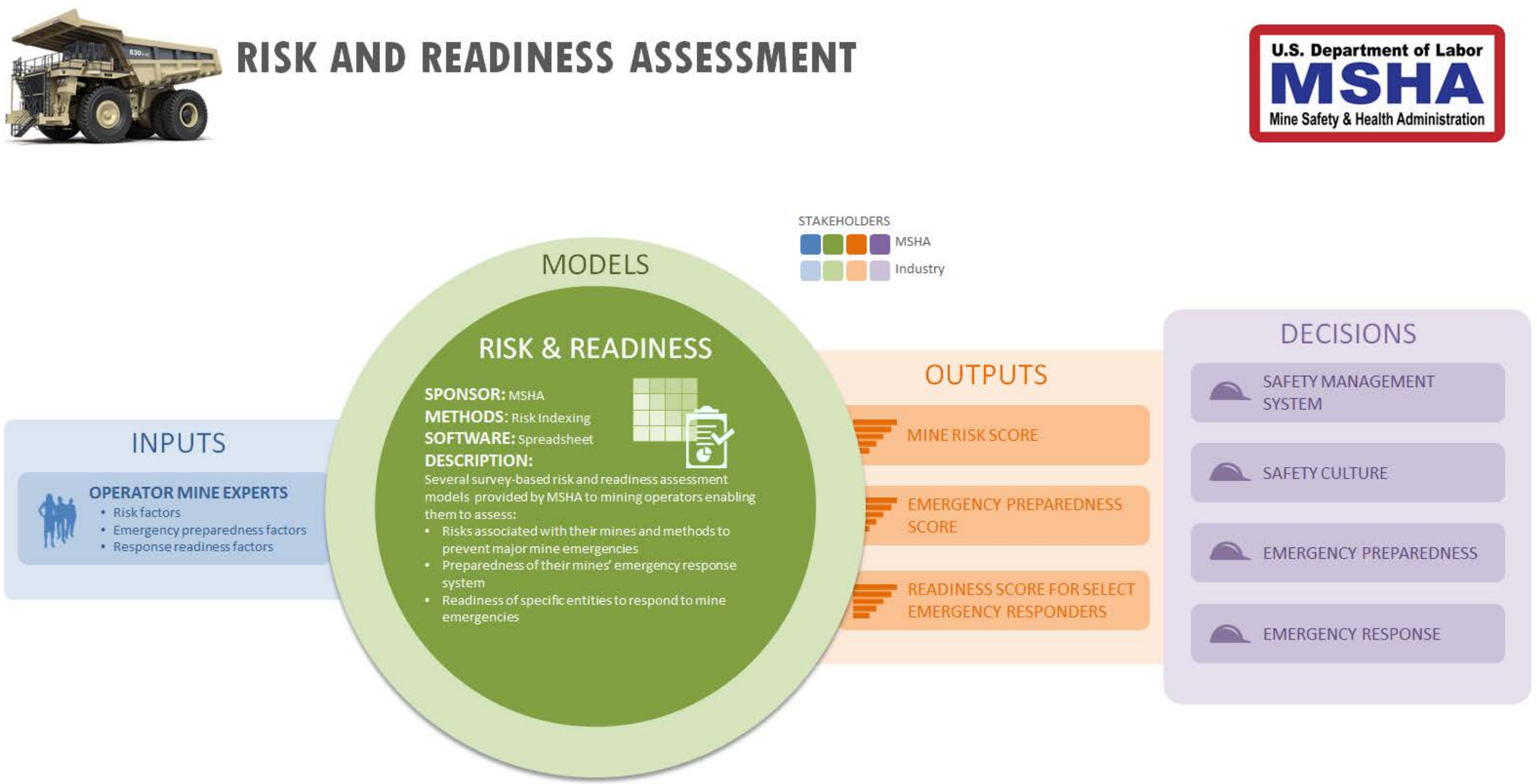


Figure E2. MSHA Risk and Readiness Assessment: Program Overview

Table E4. MSHA Risk and Readiness Assessment: Program Details

MSHA Risk and Readiness Assessment: Program Details	
INPUTS	
Name	**Description**
Government	
No government inputs associated with this program.	
Industry	
Operator Mine Experts	**Type:** SME Judgment **Source:** Operator Mine Experts **Description:** SMEs answer a series of questions for their mine(s) related to: Risk Factors • Design and Planning Data (e.g., mine location, mine design, equipment design) • Equipment Maintenance and Reliability Data • Upkeep of Mine Infrastructure/Housekeeping Data (e.g., rockdusting, routine inspection and servicing of mine infrastructure) • Documentation and Records Data (e.g., infrastructure and equipment records/manuals, operational and maintenance history, personnel records) • Material/Parts/Equipment Data • Hazard/Defect Identification and Analysis Data • Procedures Data • Workplace Conditions/Human Factors Data (e.g., workplace layout, workload) • Training/Personnel Qualification Data • Supervision Data - Risk scores for a number of factors related to supervision, including: preparation and supervision during work • Verbal and Informal Written Communication Data • Personal Performance Data (e.g., resource/staffing, rewards/incentives, individual performance) • Equipment/Infrastructure Data • Personnel Data • Mining Conditions Data (e.g., geological setting, methane liberation) • Mining Location Data • Safety Culture Data Emergency Preparedness Factors • People: command and control, knowledge of emergency responders, mine emergency preparedness training, exercises and drills • Equipment & Resources: communications, firefighting, facilities, mine equipment, outside suppliers, and rescue equipment • Process: planning and outside resource coordination Response Readiness Factors • People: competencies, training, leadership, and organization • Equipment & Resources: mine rescue resources • Process: procedures
MODELS	
Name	**Description**
Government	
Risk and Readiness Assessment Models	This program provides multiple, MSHA-developed, survey-based risk and readiness assessment models to mining operators enabling them to assess: (1) risks associated with their mines and methods to prevent major mine emergencies, (2)

	preparedness of their mines' emergency response system, and (3) readiness of specific entities to respond to mine emergencies. • **Methods:** The Risk and Readiness assessment models employ a survey-based risk indexing methodology where SMEs answer a series of questions for each major topic with numerical weights assigned to each answer. Total risk, preparedness, and readiness scores are then calculated as a function of the individual scores. • **Software:** Tools are customized MS Excel spreadsheets.
Industry	
No industry models associated with this program.	
OUTPUTS	
Name	**Description**
Government	
No government outputs associated with this program.	
Industry	
Mine Risk Score	Qualitative description of mine's status in each of the risk factor areas and aggregate quantitative risk score. All scores are compared to expected industry performance to put mine's risk in context.
Emergency Preparedness Score	Categorization of mine's status in each of the preparedness factor areas and aggregate preparedness score.
Readiness Score for Select Emergency Responders	Categorization of an emergency response team's readiness status in each of the response readiness factor areas and aggregate response readiness scores for each team.
DECISIONS	
Name	**Description**
Government	
No government decisions informed by this program.	
Industry	
Safety Management System	Risk scores inform overall understanding of the mine's base risk and the risk associated with various mining activities. Tool provides sample recommendations to inform improvement initiatives.
Safety Culture	Risk scores inform overall understanding of the mine's safety culture and provides sample recommendations to improve it.
Emergency Preparedness	Emergency preparedness scores inform overall understanding of the mine's preparedness to respond to a major mine emergency and identifies gaps in preparedness factors to inform improvement initiatives.
Emergency Response	Readiness scores inform overall understanding of the each team's readiness to response to a major mine emergency and identify gaps in each team's response readiness factors to inform improvement initiatives.

E.3. BSEE RBI

BSEE is responsible for regulating offshore petroleum activities with the purpose of ensuring the conservation of the environment and natural resources and the protection of the workforce on offshore facilities. In this capacity, BSEE performs inspections of facilities and develops the industry regulations. As is often the case in high-technology industries, rapidly emerging technologies, increasing exploration, and growing production have made it challenging for BSEE to maintain sufficient controls through traditional means. BSEE is developing its risk-based, data-driven capabilities in order to anticipate future risks and develop systematic methods of maintaining efficient and targeted regulatory solutions.

The Risk-Based Platform Inspection Prioritization model concept is straightforward: analyze platform data in order to find out the likelihood and severity of accidents on that platform. Prior attempts at similarly purposed models demonstrated that sophisticated modeling inhibits the use of such a risk index function, so this model was developed on the principle that simple is better. Using only six variables from easily accessible data sources, the model produces a coarse risk-scoring formula.

Table E5 provides summary information about the program.

Table E5. BSEE Risk-Based Platform Inspection Prioritization: Program Attributes

Attribute	Description
Origin Date	**2013**
Analytical Complexity	**Simple**
Program Maturity	
Frequency of Use	**Annual** – The model is designed with the assumption of an annual prioritization.
Risk Management Support to Mission Scope	**Narrow** – Focuses on platform prioritization for BSEE inspection activities
Government Level of Effort	**Low** –Statistical analysis effort performed by government representatives.
Point of Contact	**Jarvis Abbott**, jarvis.abbott@bsee.gov

Figure E3 provides an overview of the BSEE Risk-Based Platform Inspection program by identifying the key inputs to the analysis process, the models used, the outputs of the models, and the decisions informed by the analysis. Table E6 provides details about each element presented in the figure.

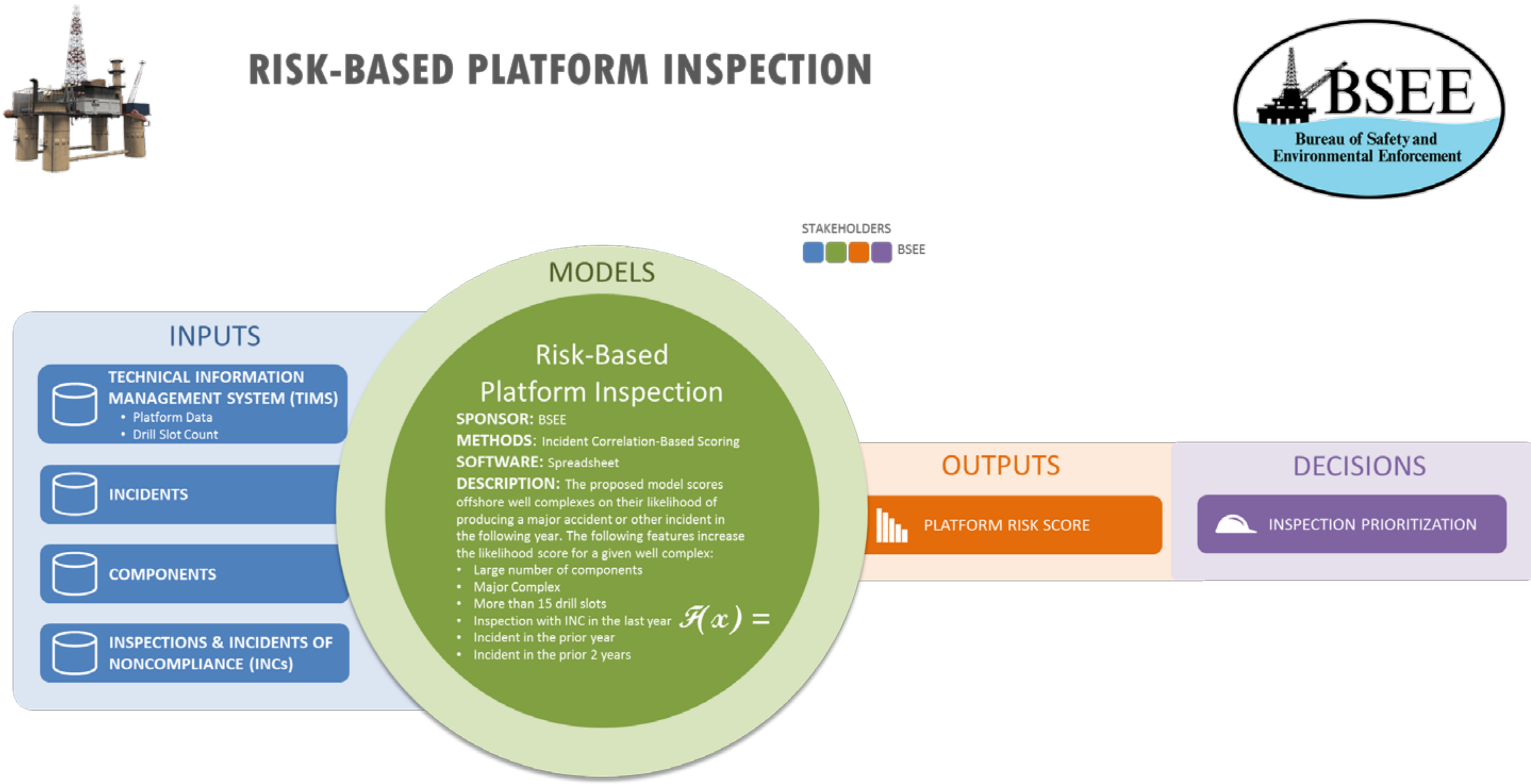


Figure E3. BSEE Risk-Based Platform Inspection: Program Overview

Table E6. BSEE Risk-Based Platform Inspection: Program Details

<table>
<tr><th colspan="2">BSEE Risk-Based Platform Inspection: Program Details</th></tr>
<tr><td colspan="2">INPUTS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td>Technical Information Management System (TIMS)</td><td>Type: Database
Source: Supplied to BSEE
Description: The TIMS database stores all of BSEE's Platform description data. For every platform, TIMS stores information about its production level, leasing information, construction, geographic location, surrounding water conditions, and a multitude of other platform features. Although many TIMS data fields were analyzed in the model-building process, only two were selected for use in prioritization of platform inspections:
• Whether or not the platform is indicated as a "Major Complex"
• Whether or not the platform has more than 15 drill slots</td></tr>
<tr><td>Incidents</td><td>Type: Database
Source: Incident Reports
Description: The Incident data stored in this database is geared toward indicating injuries, fatalities, fires, explosions, spills, and blowouts rather than subjective incident data such as near misses. The platform inspection prioritization uses the incident data to construct the following indicator variables:
• Whether or not there was an incident in the prior year
• Whether or not there was an incident in the prior two years</td></tr>
<tr><td>Components</td><td>Type: Database
Source: Industry Reporting
Description: This database provides a component count for each platform.</td></tr>
<tr><td>Inspections & Incidents of Noncompliance (INCs)</td><td>Type: Database
Source: Inspection Results
Description: This database records historical Incidents of Noncompliance. Although these incidents are categorized, the model is only concerned with whether or not any INCs were recorded for a given platform within the past year.</td></tr>
<tr><td colspan="2">Industry</td></tr>
<tr><td colspan="2">No industry data associated with this program.</td></tr>
<tr><td colspan="2">MODELS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td>Risk-Based Platform Inspection</td><td>This model is not currently in use, but is intended to provide a simple algorithmic way of prioritizing platform inspections. The proposed model was built using correlation analysis to compare a wide variety of platform metrics to the occurrence of incidents on those platforms in the following year. The scoring formula looks at the number of components making up the rig as a proxy variable for incident consequence, under the assumption that more components implies more production, which implies more capacity for large fires and spills.

For an incident frequency proxy variable, it uses the sum of the following indicator variables (1 if true, 0 if false):
• Platform is a major complex
• Platform has more than 15 drill slots
• Platform had an inspection with INC in the last year
• Platform had an incident in the prior year
• Platform had an incident in the prior 2 years
The model produces a risk score by taking the consequence proxy variable and</td></tr>
</table>

<table>
<tr><th colspan="2">BSEE Risk-Based Platform Inspection: Program Details</th></tr>
<tr><td></td><td>multiplying by the frequency proxy variable.
Methods: In reality, this model is a simple formula plus the assumption that a platform that is scored higher using the formula is more likely to have an incident in the following year. However, this formula also encodes the correlation analysis that was used to develop the formula. For that reason, the method used by this model can be described as an incident correlation-based scoring method.
Software: Spreadsheet</td></tr>
<tr><td colspan="2">Industry</td></tr>
<tr><td colspan="2">No industry models associated with this program.</td></tr>
<tr><td colspan="2">OUTPUTS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td>Platform Risk Score</td><td>Each platform is scored using the formula described above. A higher score indicates higher priority for inspection.</td></tr>
<tr><td colspan="2">Industry</td></tr>
<tr><td colspan="2">No industry outputs associated with this program.</td></tr>
<tr><td colspan="2">DECISIONS</td></tr>
<tr><td>Name</td><td>Description</td></tr>
<tr><td colspan="2">Government</td></tr>
<tr><td>Inspection Prioritization</td><td>The model prescribes that higher-scoring platforms be inspected first. Although the algorithm may appear overly-simplistic, it may provide sufficient information for the task of inspection prioritization, given that in-depth analysis is not guaranteed to produce more accurate results.</td></tr>
<tr><td colspan="2">Industry</td></tr>
<tr><td colspan="2">No industry decisions associated with this program.</td></tr>
</table>

F. IRF Agency Profiles

This appendix will contain detailed profiles for international agencies reviewed as part of this project and hyperlinks to key references.

F.1. ANP

Table F1 provides detailed information about ANP.

Table F1. Agency Overview for ANP

ANP	
Country of Origin	Brazil
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	**Director General of ANP**, Magda Chambriard: magda@anp.gov.br Telephone: +55 (21) 2112-8108 **Director (Safety Engineering),** Florival Rodrigues de Carvalho: florival@anp.gov.br Telephone: +55 (21) 2112-8353 / +55 (21) 2112-8155 **Superintendent of Marketing and Movement of Petroleum, Natural Gas and its Derivatives**, Jose Cesario Cecchi: jcecchi@anp.gov.br **Chief of Staff of ANP**, Silvio Jablonski: sjablonsk@anp.gov.br Telephone: +55 (21) 2112-8110 / +55 (21) 2112-8109
HISTORICAL BACKGROUND/SUMMARY OF MISSION: The ANP is the regulatory body for activities that integrate the oil, natural gas and biofuels industry in Brazil. It is part of Brazil's Ministry of Mines and Energy. As a federal entity responsible for implementing national policy for these sectors, ANP focuses on guaranteeing fuel supply and protecting consumer interests. ANP, implemented by Decree No. 2,455, of January 14, 1998, is the regulator of the activities within the petroleum and natural gas and biofuels in Brazil. ANP is also responsible for implementing the national policy for the energy sector on oil, natural gas and biofuels, according to the Petroleum Law (Law No. 9478/1997). The ANP is also a referral center for data and information on the oil and gas (O&G) industry. ANP promotes studies on the petroleum potential and the development of the sector; receiving and making public reports of findings; disseminates official statistics on reserves and production in Brazil; conducts periodic surveys on quality of fuels and lubricants, and pricing these products. In regards to biofuels, ANP maintains and disseminates data on permits, production and marketing of biodiesel and ethanol. ANP also keeps a Database Exploration and Production (BDEP) which, founded in May 2000, stores, organizes and makes available geophysical, geological and geochemical information. The database, after processing and analysis, provides help to the areas of sedimentary basins where there's more probability of oil and natural gas. The data acquisition and management of this collection guarantees Brazil the potential of knowledge generated in hydrocarbons. Among other duties, ANP promotes studies to identify potential oil reserves, regulates the execution of these works, organizes and maintains the collection of information and technical data. The ANP has also acted as a promoter of the development of regulated industries and collaborates with them to attract investments, technological development and training of human resources in the industry. Finally, ANP works to ensure compliance with the rules in the regulated industry activities, directly or by agreements with other public authorities. ANP also encourages growth and consolidation of the national industry of oil and natural gas-related materials,	

ANP
equipment, systems and services. This policy has a positive impact on the overall economy. Since 2003, the Agency requires commitment from companies participating in auctions for exploration and production areas to acquire a certain percentage of goods and services from Brazilian suppliers. This is the so-called "local content," which since 2005 has become one of the criteria to assess the proposals from bidding companies in the concession auctions. ANP also makes sure that these commitments are met. **ANP Regulations** The ANP also regulates the national fuel supply by working closely with various regulated agents that comprise this market: producers, importers, transporters, distributors and retailers, among others. Through regulations, requirements and rules are defined for the exercise of these activities in order to ensure stability and dynamism to the market, quality products marketed, operational and environmental safety in the facilities involved and respect the rights of the consumer. The significant number of sites involved (about 95,000) is a great challenge and great demand dialogue with the regulated market, because regulation should encompass extremely different realities about the size of the economic agents, the geographical area, and the very diversity activities that contribute to the supply of fuel. Considered of strategic importance, the national fuel supply is declared as a public utility under Brazilian law. In this sense, it is the Brazilian consumer for which ANP ensures the quality and supply of fuel throughout Brazil. In exercising that power, ANP prepares and publishes technical resolutions regulating the system within the national fuel supply, currently composed of almost 100,000 economic agents operating at different levels activities. More than 300 economic agents are authorized by ANP in the segments of liquid fuels, solvents, LPG, asphalt and jet fuel. Since 2004 the market experienced steady growth. In 2012, the distributors have sold nearly 130 million cubic meters, 6% more than the previous year. Sales of gasoline and diesel C represented over 70%. ANP publishes a yearly document called, "*The Regulatory Agenda*," which indicates the regulatory activities proposed by the ANP, for example, the years 2013 and 2014. This important planning tool is designed to allow greater predictability in regulatory action, better social participation and hence more effectiveness to the normative acts. The inclusion of material in the Regulatory Schedule does not require ANP to regulate it, nor excludes the possibility of regulation of other matters, but is an important indication of the topics that the ANP treated and on which it will consult the market and society in general. The Regulatory ANP Schedule 2013-2014 is organized into eight Thematic Platforms, which bring together the themes prioritized for this period and, therefore, constitute the focus of regulatory action of ANP. With the publication of its first Regulatory Agenda, the ANP extended the transparency of its actions, strengthens their commitment to society and provides greater security to the regulated sector. **ANP Standards for Operational Safety** ANP approves and supervises both offshore and onshore O&G exploration and production facilities (production platforms, drilling rigs, collection stations and onshore wells). Equipment and procedures for treatment, storage, gas processing and moving oil and natural gas also require the Agency's authorization, and are among its inspection targets. The regulatory system of Brazilian offshore operational safety (ANP Resolution No. 43/2007), is regarded as one of the most modern in the world, and is based on a comprehensive study of the regulations adopted in countries such as Australia, Canada, Norway, the UK and USA, and on the learning gained from accidents. Within this ANP Resolution is the basis of ANP's Operational Safety Guidance which includes minimum requirements of: Mechanical Integrity, Risk Assessment, Contractors Selection, Internal Audits, Incident Investigations, Management of Change, Safe Working Practices, and Simultaneous Operations. Documentation for Operational Safety compliance by ANP is separated into three distinct areas of focus; 1) Management, Leadership and Personnel, 2) Facilities and Technology, and 3) Operational Practices.

ANP
ANP also participates in the International where topics of operational safety are discussed with the purpose of raising offshore health and safety standards. The ANP Safety Regulations and Data Manuel guide the identification of hazards and risk assessment of each facility.
ORGANIZATION COLLECTION METHODS OF RISK DATA (RISK INVENTORIES, RISK REGISTERS, TOLERANCE AND ACCEPTANCE LEVELS) **Credibility of Brazilian Standards for Operational Safety** The Brazilian regulatory regime of maritime operational safety has been built based on extensive study of the policies adopted in countries like the United States, Canada, Norway, UK and Australia, and acquired in the practice of supervision and learning, in particular from the analysis of the two major accidents that occurred in the Campos Basin; the sinking of the P-36 in 2001 as well as the loss of stability of the P-34 in 2002. The set of rules established by ANP is based on the hazard identification and risk assessment of the processes and operations of each facility. In accordance with safety practices set forth in ANP Resolution No. 43/2007, dealers must prove the maintenance of controlled risks arising from any operation performed on the premises of offshore drilling and production. Inspections of facilities, operation tests on critical safety equipment, interviews with staff and reviews of documentation are among the procedures which are done during ANP audits of offshore facilities. ANP's procedural approach, where the central focus is on the verification of compliance with safety management practices, is an improvement over a prescriptive regime, in which the details of the requirements for facilities and equipment platforms limits the technological development of the sector, that is constantly evolving. The activities on offshore platforms are mandatory to comply with the Management of Operational Security System Installations Marine Drilling and Production of Oil and Natural Gas (SGSO) of ANP. The SGSO was established in 2007 by Resolution #43 (i.e. ANP Resolution No. 43/2007) and its Operational Safety Technical Regulation for Maritime Facilities Exploration and Production (E&P). Compliance with these regulations is required in contracts signed by ANP on behalf of the Union (i.e. Brazil), with the winning companies that provided details during the original rounds of bidding. **Safety Requirements Prior to Beginning Operations** To obtain permission to begin operations, each dealer must submit to ANP a collection of documents that prove their adequacy standards of the Technical Regulation Operational Safety Facilities for Marine Exploration and Production, otherwise known as the SGSO, established by ANP Resolution No. 43/2007. The documentation is evaluated by the Coordination of Operational Security (CSO) and submitted to the Board of the ANP. Since 2008, ANP has analyzed more than 900 versions of collections of operational security documents, averaging 190 analysis reports per year. Of these analysis documents, 25% of these were recommended to the Board of Directors for approval whereby the remaining 75% resulted in requests to dealers to be fitted to the specifications outlined in ANP Resolution No. 43/2007. In case of "incident," the utility company must report the event immediately to ANP, in accordance with standards and procedures contained in ANP Resolution No. 44/2009, which outlines procedures for incident reporting by dealers and companies authorized by ANP to exercise activities of the oil industry, natural gas and biofuels, as well as distribution and resale. ANP Resolution No. 44/2009 defines "incident" as, "any occurrence, event or due to intentional or accidental act involving: harm or risk of harm to the environment or human health, materials to own equity or third party damage, occurrence of fatalities or serious injury to their own staff, to others or to populations or unscheduled interruption of operations by more than 24 (twenty four) hours."
ORGANIZATION APPLICATION OF RISK DATA **Collection and Application of Data** After the start of operations, the ANP finds, audits the edge of the platform, implementation of the 17 management practices mandatory safety on drilling rigs, production, stockpiling and transfer, which are provided in the 40 pages of ANP Resolution No. 43/2007. These practices include issues relating to: management of the facility, training of personnel, mechanical integrity, hazard identification and risk analysis, change management, selection of contractors, safe work practices and simultaneous operations.

ANP
The priority for execution of audits is defined based on various parameters associated with risk, as the complexity of the process plant; water depth; age at onset; history of incidents; previous audits and inspections. In the case of ANP identifying any deviations of safety management systems, oil and drilling companies are contractually obligated to resolve non-conformities detected, in terms established by ANP. If non-compliance is critical, all operations of the platform are prohibited and shut down. The annual reports of the operational safety of the exploration and production of oil and natural gas in 2010, 2011 and 2012 activities show the results of inspections conducted by ANP aboard the offshore drilling and production platforms operating in Brazilian waters. They also include statistics from incidents reported by companies in the exploration and production of O&G in onshore and offshore fields. With the publication of these reports, ANP demonstrates how it is being held accountable to society for its work overseeing the operational safety, which is one of its main tasks. The intensification of surveillance on board by ANP in recent years has caused an increase in incident reporting by companies, which are now even informing ANP of operational incidents that did not cause harm to human health and the environment. In 2011, ANP, in the realm of operational safety, conducted 59 enforcement activities on board the platforms, the servers on which the agency evaluated the safety of drilling and production plant of maritime units systems. In addition, 1,038 technical inspections were conducted in marine systems (structure, ballast, communication, anchoring etc.), based on mutual cooperation between ANP and the Navy of Brazil. The number of oil spills or derivatives fell from 86 in 2010 to 79 in 2011. The leaked volume in 2011 was approximately 3,800 barrels, of which about 3,700 correspond to the accident at Frade Field.
REFERENCES • ANP Background: http://www.anp.gov.br/?id=2714 • ANP Operational Safety: HTTP://WWW.ANP.GOV.BR/?ID=1606 • ANP Resolution No. 43/2007: http://nxt.anp.gov.br/NXT/gateway.dll/leg/resolucoes_anp/2007/dezembro/ranp%2043%20-%202007.xml?f=templates$fn=document-frame.htm$3.0$q=$x=$nc=7478 • ANP Resolution No. 44/2009: http://nxt.anp.gov.br/NXT/gateway.dll/leg/resolucoes_anp/2007/dezembro/ranp%2043%20-%202007.xml?f=templates$fn=document-frame.htm$3.0$q=$x=$nc=7478 • ANP Annual Reports on Operational Safety Activities: http://www.anp.gov.br/?pg=67683&m=&t1=&t2=&t3=&t4=&ar=&ps=&cachebust=1412966284054 • ANP Online Lectures Library: http://www.anp.gov.br/?pg=71193 • ANP Operational Safety PowerPoint: http://www.icrard.org/upload/ICRARD%202010%20Final%20Presentation%20-%20Brazil.ppt • ANP Safety Regulations and Data Manuel: http://www.anp.gov.br/?dw=603

F.2. C-NSOPB

Table F2 provides detailed information about C-NSOPB.

Table F2. Agency Overview for C-NSOPB

C-NSOPB	
Country of Origin	Canada
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	**Board Member (Provincial) Acting Chairperson**, Tim Brownlow Telephone: +1 (902) 422-5588

C-NSOPB	
	Chief Executive Officer, Stuart Pinks spinks@cnsopb.ns.ca Telephone: +1 (902) 496-3206 **Chief Safety Officer/ Director- Operations/Health**, Keith Landra klandra@cnsopb.ns.ca Telephone: +1 (902) 496-0723 **Director, Regulatory Affairs & Finance**, Christine Bonnell-Eisnor cbonnell@cnsopb.ns.ca Telephone: +1 (902) 496-0745

HISTORICAL BACKGROUND/SUMMARY OF MISSION:

C-NSOPB is the independent joint agency of the Governments of Canada and Nova Scotia responsible for the regulation of petroleum activities in the Nova Scotia Offshore Area. It was established in 1990 pursuant to the *Canada-Nova Scotia Offshore Petroleum Accord Implementation Acts* (aka, the Accord Acts), which implement the 1986 *Canada-Nova Scotia Offshore Petroleum Resources Accord*. The Acts were passed as mirror legislation by the Parliament of Canada (1988) and the Legislature of Nova Scotia (1987). The Board reports to the federal Minister of Natural Resources Canada in Ottawa, Ontario, and the provincial Minister of Energy in Halifax, Nova Scotia. Its mission is to be the efficient, fair and competent regulation agency of exploration and production activities enabling safe and responsible development of Nova Scotia's offshore petroleum resources.

Objectives and Roles

The C-NSOPB is respected both locally and internationally for its proficient regulation of offshore petroleum activities providing high benchmarks for others to emulate. Its mandate is to apply the provisions of federal and provincial Accord Act legislation governing offshore oil and gas activities, including: Health and safety of workers; Protection of the environment; Management and conservation of petroleum resources; Canada-Nova Scotia employment and industrial benefits; Issuance of licenses for exploration and development; and; Resource evaluation, data collection, curation and distribution. Organizational decision making is structured in a manner that recognizes safety as paramount and environmental protection as second only to safety.

The C-NSOPB does not, however, regulate electricity, natural gas distribution, oil and gas prices, or Liquefied Natural Gas (LNG). In addition, they do not set energy, economic development, climate change or environmental policy objectives since those responsibilities reside with the government. C-NSOPB also does not guarantee or set targets for the participation of the Nova Scotian or Canadian workforce in offshore projects, nor administer equalization, taxation or royalty regimes for offshore developments as those responsibilities also reside with government.

Areas of Responsibility (AOR)

In regards to petroleum production offshore projects, Nova Scotia has, or had, maintained three particular projects. The first was the Cohasset-Panuke project, which produced oil from 1992 -1999 and is now decommissioned. Project operators were Pan Canadian (now Encana), and Lasmo. The Cohasset - Panuke Project operated from 1992 to 1999, producing a total of 7.1 E6M3 of oil (44.5 MMBbls). When it began production in 1992, it became Canada's first offshore oil project. The project was developed by LASMO Nova Scotia Limited, in partnership with Nova Scotia Resources (Ventures) Limited. PanCanadian (EnCana) acquired LASMO's 50% ownership in January 1996 and became operator of the project. Decommissioning of the project is now complete, with the exception of ongoing environmental follow-up, expected to be complete by Q4 2009.

Next is the Sable Offshore Energy Project (SOEP), operated by Exxon Mobil and partners, which has been producing gas since 1999. SOEP involves the development of natural gas fields near Sable Island which is located approximately 225 km off the east coast of Nova Scotia. The six fields are: Venture, South Venture, Thebaud, North

C-NSOPB

Triumph, Glenelg and Alma. Together, these fields contain an estimated 85 billion cubic meters (3 TCF) of recoverable gas reserves and 11.9 million cubic meters (74.8 MMbbl) of condensate. SOEP is operated by ExxonMobil Canada Ltd. with its partners Shell Canada Limited, Imperial Oil Resources Limited, Pengrowth Corporation, and Mosbacher Operating Ltd. Production began in December 1999 with a total project life expectancy of about 25 years, however new discoveries could extend that project life. The project design rate is 14.4 E6M3/d of raw gas (510 MMscf/d) production yielding 13 E6M3/d of sales gas. This production rate can be increased if market conditions and gas supplies warrant.

The SOEP gas fields are being developed in two tiers. Tier I fields are Thebaud, Venture and North Triumph. Thebaud began production December 31, 1999 followed by Venture and North Triumph in February 2000. Tier II fields are Alma, South Venture and Glenelg. Alma began production in November 2003 followed by South Venture in December 2004. The Glenelg field is presently under review by ExxonMobil and partners. A total of 28 development wells are proposed for the six fields. These were and will be drilled using jack-up rigs. The number and sequence of wells will be subject to adjustment throughout the Project depending on drilling results, production performance and market conditions.

In Tier I, central facilities are installed at Thebaud for production, utilities and accommodation. Satellite platforms are located at Venture and North Triumph. These are unmanned wellhead and production platforms. The Thebaud platform has systems for remote monitoring and control of the other platforms. Each of these unmanned platforms is equipped with small emergency quarters and a helideck. Hydrocarbons produced at these platforms are transported through a system of subsea flow lines to the Thebaud platform. Unprocessed gas from the fields is separated and dehydrated at the Thebaud platform. The separated gas and hydrocarbon liquids and condensates are then recombined and transported through a subsea production gathering pipeline to landfall in the Country Harbour area of Guysborough County, Nova Scotia and then to a gas processing plant at nearby Goldboro. There, the gas is conditioned by removing natural gas liquids, condensates and remaining water. The sales gas then flows to markets in eastern Canada and the northeastern United States through an onshore pipeline. Natural gas liquids and condensate are transported by another onshore pipeline to a fractionation plant at Point Tupper for further processing before being sold.

In Tier II, offshore platform Alma began operation in late 2003 followed by production from the South Venture platform in late 2004. In 2006, the Sable Tier II compression project began with the installation of a compression platform, which is bridge-connected to the Thebaud central processing facilities. These compression facilities were part of the approved Development Plan Application file for SOEP. The compression platform has been in operation since early 2007.

Finally, the last project is the Deep Panuke Offshore Gas Project, operated by Encana Corporation and partners, which started producing gas in 2013. Encana's Deep Panuke Offshore Gas Development Project involves the production of natural gas from an offshore field located approximately 250 km southeast of Halifax and the transportation of that gas via subsea pipeline to shore, and ultimately, to markets in Canada and the United States. Production is anticipated to continue for a mean production life of 13 years. Over the life of the project, up to 25.1 E9M3 (892 Bcf) of natural gas will be produced through a facility sized for a peak gas rate of 8.5 E6M3/d (300 MMscf/d). The project will utilize a jack-up type offshore platform as its Production Field Centre (PFC), tied back to production wells with subsea flow lines and umbilical's. The Canada-Nova Scotia Offshore Petroleum Board (CNSOPB) approved, with conditions, the Deep Panuke Canada Nova Scotia Benefits Plan and Development Plan on September 10, 2007.

ORGANIZATION COLLECTION METHODS OF RISK DATA (RISK INVENTORIES, RISK REGISTERS, TOLERANCE AND ACCEPTANCE LEVELS)

Risk Data Collection through Requirements For Offshore Operations

Operators are required to meet certain regulatory requirements before the Board can approve offshore petroleum related activities. The regulatory framework which governs offshore petroleum operations consists of the Accord Acts, its regulations, and Board guidelines and policies. The Board is also a Federal Authority under the Canadian

C-NSOPB

Environmental Assessment Act (CEAA) and follows the environmental assessment process outlined in the CEAA. The Board's regulatory regime is based upon Federal legislative models and regulations developed in consultation with other petroleum regulators in Canada and abroad. The regime is also very similar to that which exists in the Newfoundland and Labrador offshore area.

In regards to Offshore Activity Authorizations, no activities related to the exploration for, development of or transportation of petroleum can be conducted without a specific authorization issued by the Board. The Board must be satisfied with the information provided before it will issue a work or activity authorization. Prior to issuing any such authorizations, the Board requires that the following be submitted in a satisfactory form:

- Canada-Nova Scotia Benefits Plan;
- Development Plan (for development related activities);
- Safety Plan;
- Environmental Assessment;
- Environmental Protection Plan;
- Spill Contingency Plan;
- Financial Security;
- Summary of Proposed Operations;
- Certificate of Fitness (if applicable), and
- Declaration of Operator

Overview of Requirements

Before carrying out any work or activity in the offshore area, an operator must first obtain an operating license which is valid for one fiscal year (April 1st to March 31st), and a work authorization from the Board based on the plans submitted by the operator that were found to be in satisfactory form. Where an operator seeks an authorization to carry out any work or activity relating to developing a pool or field an operator must submit a Development Plan to the Board for approval. This requirement may be waived with the consent of both provincial and federal governments.

The purpose of a Development Plan is to provide an overview of the proposed development and provide sufficient information so that the plan can be assessed by the Board to satisfy itself that the development can be undertaken safely, while protecting the environment and maximizing resource recovery. Information on filing requirements for Development Plans is contained in *Guidelines on Plans and Authorizations Required for Development Projects*. An approval of a Development Plan by the C-NSOPB does not grant a proponent authority to undertake any work in the offshore area. Therefore the details of these activities are not included in the Development Plan; they must be submitted when the application for approval of the actual activity is submitted.

A certificate of fitness is required for certain equipment and installations, including drilling, production, diving, and accommodation installations. A certificate of fitness is issued by a Certifying Authority (CA) that has met the criteria established by regulation and is named in the Nova Scotia Offshore Certificate of Fitness Regulations. These CAs are required to review the design, construction, installation and operating manuals for the installation and certify to the Board that the installation is fit for its intended purpose, that it is in compliance with the regulations and that it can be operated safely without polluting the environment. The Board cannot issue an authorization unless there is a certificate in place for the installation.

A Declaration of Operator is also required for all activities. This declaration is signed by a senior officer of the operator and states that this person has undertaken, or caused to be undertaken, sufficient work to satisfy the officer that the equipment is fit for purpose, and the personnel are properly trained so that the activity can be

C-NSOPB
undertaken safely. **Incident Reporting** Operators are required to report environmental and health & safety incidents to the C-NSOPB in accordance with criteria set out in regulations and detailed in the Incident Reporting and Investigation Guidelines. Reporting to the C-NSOPB by the operator includes: • Incident Notification (immediate verbal, immediate written and written notification depending on the nature of the incident); • Incident Investigation Reports (due within 21 days of occurrence, all reported incidents are to be investigated by the operator to determine information such as root cause and actions to prevent reoccurrence); • Operators direct all immediate verbal notifications to the CNSOPB at +1 (902) 496-4444. Written notification (including immediate) is submitted to the CNSOPB by E-mail. For each incident reported, the C-NSOPB verifies that the operator takes the appropriate actions to determine the cause of the incident and to prevent its reoccurrence. Pursuant to the Board's compliance and monitoring processes, CNSOPB staff may also investigate health, safety and environmental incidents that occur at offshore worksites, depending upon their nature and severity. For significant spills, hydrocarbon releases and unauthorized discharges, the Board assesses the potential environmental impact. In addition to following up on these incidents, the C-NSOPB also monitors whether trends are occurring. Environmental concerns include the potential impact of sea-surface petroleum products on seabirds and the marine habitat. **Environmental Assessments (EAs)** The C-NSOPB's responsibility for environmental protection includes ensuring EAs are conducted for exploration projects and any other offshore petroleum projects for which an EA is not required pursuant to CEAA 2012. EAs required by the C-NSOPB are referred to as Accord Act EAs. Accord Act EAs and their associated documentation, as well as EAs conducted under the Canadian Environmental Assessment Act, are available on this Public Registry and the Public Registry Archives.
ORGANIZATION APPLICATION OF RISK DATA **Safety Compliance and Enforcement Application** The C-NSOPB has in place an effective monitoring program to evaluate operator compliance with health and safety regulatory requirements while conducting authorized petroleum related work activities. Operators are required to submit reports detailing the status of their work programs on an ongoing basis, along with other documentation to demonstrate compliance with regulatory requirements. Operational status reports are provided on a daily basis for drilling and production activities, and on a weekly basis for other activities. Reports filed with the C-NSOPB are reviewed by staff to identify health and safety compliance issues, and such issues are addressed accordingly. The Board also routinely reviews minutes from Joint Occupational Health & Safety (JOHS) Committee meetings held offshore to ensure that health and safety matters raised through this forum are dealt with appropriately by the operator. CNSOPB staff may also investigate health and safety incidents that occur at offshore worksites, depending upon their nature and severity. This includes investigations into worker complaints and work refusals. An investigation is normally conducted using safety officer powers granted by the Accord Acts However, in cases where a safety officer has reasonable grounds to believe an offence has been committed; the investigation is conducted taking into account limitations imposed by the *Canadian Charter of Rights and Freedoms*. The Board has a key accountability to take necessary enforcement actions so that non-compliances with regulatory requirements are corrected by operators. The C-NSOPB has an established compliance and enforcement policy to address situations of regulatory noncompliance. Enforcement actions may include: Authorities/command structure; voluntary compliance; issuance of orders,

C-NSOPB
directives or notices; suspension or revocation of approvals and authorizations; and prosecution in the court system.
REFERENCES • C-NSOPB Reference Materials: http://www.cnsopb.ns.ca/reference • C-NSOPB Operating License Form: http://www.cnsopb.ns.ca/OP_forms/OperatingLicenceForm.pdf • C-NSOPB Offshore Activity Authorization Forms: http://www.cnsopb.ns.ca/offshore-activity/activity-authorizations • C-NSOPB Declaration of Operator: http://www.cnsopb.ns.ca/OP_forms/DeclarationofOperator.pdf • C-NSOPB Certificate of Fitness: http://www.cnsopb.ns.ca/OP_forms/CertificateofFitnessForm.pdf • C-NSOPB Location Map of Offshore Platforms: http://www.cnsopb.ns.ca/pdfs/sable_area_platforms.pdf • C-NSOPB Drilling Authorization Form: http://www.cnsopb.ns.ca/sites/default/files/pdfs/operations_authorization_drilling.pdf • C-NSOPB Production Authorization Form: http://www.cnsopb.ns.ca/OP_forms/Operations_Authorization_Production_Application.pdf • C-NSOPB Incident and Reporting Guidelines Update: http://www.cnlopb.ca/johsc/kweir.pdf

F.3. C-NLOPB

Table F3 provides detailed information about C-NLOPB.

Table F3. Agency Overview for C-NLOPB

C-NLOPB	
Country of Origin	Canada
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	**Chairman & CEO of C-NLOPB**, Scott Tessier stessier@cnlopb.ca Telephone: +1 (709) 778-1400 **Vice-Chairman of C-NLOPB**, Ed Williams ewilliams@cnlopb.ca Telephone: +1 (709) 778-1400 **Manager of Public Relations**, Sean Kelly skelly@cnlopb.ca Telephone: +1 (709) 778-1418 Cell: (709) 689-0713 **Director of Safety & Chief Safety Officer**, Daniel B. Chicoyne dchicoyne@cnlopb.ca Telephone: +1 (709) 778-1400
HISTORICAL BACKGROUND/SUMMARY OF MISSION: The Canada - Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) was created in 1986 through the *Atlantic Accord* for the purposes of regulating the oil and gas industry offshore of Newfoundland and Labrador. The Board operates at arms-length from governments and reports to both the Federal and Provincial Ministers of Natural Resources. Decisions of the Board, referred to in legislation as 'Fundamental Decisions', are referred to the Canadian government for approval or rejection.	

C-NLOPB

Pursuant to the legislation, the C-NLOPB has four regulatory mandates: Safety, Environmental Protection, Resource Management and Industrial Benefits. The Board regulates exploration licenses, significant discovery licenses, and production licenses covering an area of 7,365,000 hectares; that is an area of about two-thirds of the size of the island portion of the Province of Newfoundland and Labrador.

The Board is comprised of seven persons; three appointed by the Federal Government, three appointed by the Provincial Government, and a Chair and CEO that is appointed jointly by the two governments. Board members are: Scott Tessier (Chair and CEO), Ed Williams (Vice-Chair), Ed Drover, Conrad Sullivan, Reg Anstey, Lidija Cicnjak-Chubbs and Cynthia Hickman.

The C-NLOPB's official mandate is to interpret and apply the provisions of the *Atlantic Accord* and the *Atlantic Accord Implementation Acts* to all activities of operators in the Newfoundland and Labrador Offshore Area; and, to oversee operator compliance with those statutory provisions. In the implementation of its mandate, the role of the C-NLOPB is to facilitate the exploration for and development of the hydrocarbon resources in the Newfoundland and Labrador Offshore Area in a manner that conforms to the statutory provisions for: worker safety; environmental protection and safety; effective management of land tenure; maximum hydrocarbon recovery and value; and, Canada/Newfoundland & Labrador benefits. While the legislation does not prioritize these mandates, worker safety and environmental protection will be paramount in all Board decisions.

Objectives and Roles

C-NLOPB's core objectives are Safety, Environment, and Resource Management. In regards to Safety, the C-NLOPB verifies that operators have appropriate safety plans in place (through audits and inspections), that operators follow their safety plans and applicable statutory requirements (through compliance actions), and that deviations from approved plans and applicable statutory requirements are corrected.

In regards to the Environment, C-NLOPB verifies that operators assess and provide for effects of the environment on the safety of their operations. In addition, they verify that operators perform an environmental assessment, pursuant to Canadian regulations, of the effects of their operations on the environment, and prepare a plan and provide for mitigation where appropriate. Finally, through compliance actions, they verify that operators comply with their environmental plans.

In regards to Resource Management, C-NLOPB ensures and verifies the effective and efficient administration of land tenure. They also provide oversight of production activities for consistency with maximum recovery, good oilfield practice, production accounting and approved plans. C-NLOPB also builds a knowledge base for the Newfoundland & Labrador Offshore Area through the acquisition and curation of data from exploration and production activity.

C-NLOPB also verifies if operators have an approved Canada/Newfoundland & Labrador Benefits Plan that addresses their statutory obligations.

However, C-NLOPB DOES NOT guarantee safety of workers or the environment (the operators are responsible for the protection and safety of workers and the environment). In addition, they also do not manage reservoirs or production (that is the role of the operator within the context of an approved Development Plan). Furthermore, they do not guarantee the participation of Canadian and Newfoundland & Labrador workers and businesses. Finally, C-NLOPB does not have any role, beyond the provision of required data and information to government, in the establishment or administration of the fiscal regime (royalties/taxes) for any offshore activity.

Areas of Responsibility (AOR)

There are three production facilities offshore Newfoundland and Labrador that C-NLOPB is tasked to oversee: Hibernia, Terra Nova and White Rose.

C-NLOPB
The Hibernia field, discovered in 1979, is located approximately 300 km east/ southeast of St. John's, Newfoundland and Labrador. The field, located in the Jeanne d'Arc Basin, consists of two principal reservoirs: the Hibernia and Ben Nevis-Avalon reservoirs. The Hibernia field is being produced using a Gravity Based Structure (GBS) and is operated by Hibernia Management and Development Company Ltd. (HMDC). The Terra Nova field, discovered in 1984, is located 350 kilometres east-southeast of St. John's, Newfoundland and Labrador. The field, located in the Jeanne d'Arc Basin consists of one reservoir: the Jeanne d'Arc. The field is being produced with a Floating, Production, Storage and Off-Loading vessel (FPSO) and is operated by Suncor Energy Inc. Lastly, the White Rose field, discovered in 1984, is located approximately 350 kilometres east of St. John's, Newfoundland and Labrador. The field, located on the northeastern margin of the Jeanne d'Arc Basin, has one principal reservoir: the Ben Nevis-Avalon reservoir. The field is being produced with a Floating, Production, Storage and Off-Loading vessel (FPSO) and is operated by Husky Oil. **C-NLOPB Safety Department** The C-NLOPB's Safety Department administers the *Atlantic Accord Implementation Acts* and subordinate legislation regarding the safety of persons in the Newfoundland and Labrador Offshore Area. The Department encourages persons exploring and exploiting petroleum to maintain a prudent regime for achieving safety. In the context of the legislation, the Department oversees operators' risk management with the goal of minimizing risk to persons engaged in offshore petroleum activities. Finally, the Department expects operators to make all reasonable efforts to identify all the hazards associated with their proposed operations and to implement all appropriate measures to reduce the risk from these hazards to a level that is as low as reasonably practicable. A Joint Occupational Health and Safety Committee (JOHSC) is required on each offshore installation. This committee, which is made up of equal numbers of management and worker representatives has a duty to monitor the health, safety and welfare of the workers employed at the workplace. They are required to participate in workplace inspections, establish and promote health and safety educational programs for workers, receive complaints, make recommendations for improvement to the safety management system and to identify aspects of the workplace that may be unhealthy or unsafe. The JOHSC must also be immediately notified of incidents in the workplaces and are expected to review incident investigation reports. The specific activities of the C-NLOPB Safety Department include: Safety Assessment of Work Authorizations (Declarations of Fitness); Monitoring, through the reporting and investigation of incidents, injury statistics, the JOHSC's and various complaints; and, lastly; Compliance and Enforcement, by overseeing the Chief Safety Officer and Safety Officers, performing audits and inspections, issuing orders and investigating work refusals. The C-NLOPB will be holding its first Safety Conference and Exhibition on November 13, 2014. **Chief Safety Officer and Safety Officers** Pursuant to legislation, the Board appoints the Chief Safety Officer and Safety Officers. The Chief Safety Officer is responsible for administering the health and safety provisions in the Acts for the safety and the protection of workers in the offshore area. The Chief Safety Officer can shut down an operation in whole or in part when there are reasonable grounds to believe there is a condition that is likely to cause serious bodily injury. Safety Officers are responsible for reviewing compliance with safety requirements and assessing the effectiveness of the operators' management systems. They perform monitoring, inspections and audits of offshore petroleum related activities to review compliance of safety and occupational health and safety legislative requirements or conditions of authorization. They can order an operation to cease where there is a situation likely to result in serious bodily injury. In conducting these activities, the powers of Safety Officers include the ability to: • Enter any place on land or offshore used in connection with any work or activity;

C-NLOPB

- Test, examine or inquire or direct another to perform these tasks;
- Take photographs and make drawings;
- Require the production of books, records, etc., for inspection or copying;
- Take samples; and
- Require individuals with knowledge relevant to the inspection to furnish information orally or in writing.

ORGANIZATION COLLECTION METHODS OF RISK DATA (RISK INVENTORIES, RISK REGISTERS, TOLERANCE AND ACCEPTANCE LEVELS)

C-NLOPB Authority to Collect and Analyze Risk

The *Atlantic Accord Implementation Acts* specify that the Chief Safety Officer and/or the Chief Conservation Officer may authorize the use of equipment, methods, measures or standards in lieu of any required by regulations, where those Officers are satisfied that the use of that other equipment and those other methods, measures or standards would provide a level of safety, protection of the environment and conservation equivalent to that provided by compliance with regulations. To document and process such requests from industry, along with requests to clarify the application of specific regulations in specific cases, the Board has developed a "regulatory query process", which the Operations and Safety Department administers.

If an operator or installation owner requires clarification on, equivalency for, or exemption from, a regulatory requirement, the applicant must submit a Regulatory Query Form (RQF) outlining its proposal. For regulations related to the Certificate of Fitness, the proposal must be submitted to the Certifying Authority for their concurrence with the proposal. In addition, for Canadian flagged installations, where a similar requirement is in the Canada Shipping Act and associated regulations, the proposal must also be submitted to Transport Canada Marine Safety for review. The C-NLOPB may seek advice from Transport Canada Marine Safety on proposals related to marine matters on foreign flagged installations.

Following Certifying Authority and/or Transport Canada concurrence with the proposal where required, C-NLOPB staff reviews the proposal. If C-NLOPB staff is satisfied that the applicant's proposal provides for an equivalent level of safety, they will make a recommendation to the Chief Safety Officer and/or the Chief Conservation Officer regarding the approval of the proposal.

Risk Data Collection through Safety Audits and Safety Inspections

A safety audit is a systematic evaluation of all aspects of an operation to determine overall compliance with regulatory requirements related to safety and risk management and the safety commitments made by the operator in obtaining their authorization to conduct work. The aim of the audit is to verify an operator's compliance with the regulations and their safety commitments. Safety audits also review the operator's efforts in correcting and preventing reoccurrences of instances of non-compliance or incidents. Safety audits may include the reviewing or copying of documentation and records, obtaining samples, interviews with personnel, verification of the quality of information reported to the C-NLOPB, inspection of equipment or other physical aspects of an operation, observation of operations, verification of qualifications and training of personnel and verification that the operator has appropriately addressed incidents or potential incidents of non-compliance (PINCs).

A safety inspection involves the physical presence of a Safety Officer at an operation. An inspection is normally part of the audit, but can be conducted separately from an audit and may incorporate some or all of the activities that are normally conducted during an audit. C-NLOPB safety inspections do not certify the integrity of components or their fitness for an intended purpose; certification of the integrity or fitness of a component is done by an individual or firm qualified to do so. C-NLOPB safety inspections are not detailed inspections or surveys of equipment, structures or facilities. Normally, the operator, installation owner, specialized third party contractors and the certifying authority complete these detailed inspections and surveys. In addition, members of the JOHSC may accompany the Safety Officer during a safety inspection.

During a safety audit, C-NLOPB Safety Officers can raise a non-conformance against anything that does not

C-NLOPB
conform to the Operator's safety management policies and procedures or to legislative requirements. There are two types of non-conformances: 1.) An Observation Non-Conformance: A statement of fact related to a non-conformance made during a safety audit or safety inspection and substantiated by objective evidence. 2.) A Finding Non-Conformance: A conclusion substantiated by one or more observations, which highlights significant issues with the implementation of the operator's safety management policies and procedures, adherence to legislative requirements and/or any non-conformance that has significant implications for safety. Following the issuance of an audit report, an operator has 15 working days to provide an action and timeframe that is acceptable to the C-NLOPB. The operator must take action to address non-conformances within the agreed timeframe. Failure to comply within that timeframe could result in an order to comply or, depending on the seriousness, could constitute an offence under the Act. **Risk Data Collection through Order to Comply** An "Order to Comply" is a direction from a Safety Officer or the Chief Safety Officer directing or ordering a person to correct a deficiency that is causing or has caused a compliance issue and which could constitute an offense. An Order to Comply may be issued when it appears a person is ignoring or slow to respond to a non-conformance or other non-compliance. An Order to Comply will be issued in writing and will include the reference to the section of the Act or the Regulation giving rise to the non-compliance, the reasons for issuing the Order to Comply, the conditions that must be complied with and where applicable, the process available to appeal the instruction. Failure to comply with an Order of a Safety Officer or Chief Safety Officer is an offence under the Acts. Pursuant to legislation, where the Chief Safety Officer or a Safety Officer is of the opinion that the continuation of an operation is likely to result in serious injury, then an "Order to Cease or Continue Operations" may be issued. In this event, the Chief Safety Officer or Safety Officer may order that the operation cease or be continued under specified conditions. Once issued, Orders to Comply or must be posted in prominent locations throughout the installation. Further information on the issuance and the appeal of these orders are contained within Section 193 of the Canada-Newfoundland and Labrador Atlantic Accord Implementation Act. **Risk Data Collection through Investigations** Operators normally investigate all incidents and submit a report to the Board, however, the legislation also provides the ability for the C-NLOPB to conduct an investigation into any occurrence under its jurisdiction. Thus, where Board staff suspect a violation of the legislation or receive a report of an incident, the Chief Safety Officer or Chief Conservation Officer may initiate an investigation or request an operator to conduct their own investigation. Investigations could also be initiated in the event that Board staff was not satisfied with an Operator's investigation report. If an investigation by C-NLOPB staff is required, the Chief Safety Officer and/or the Chief Conservation Officer will notify the operator of the investigation, request immediate transportation to the location, and will order the operator to ensure that the scene is preserved and secured at all times, subject to attending to damage control and medical response necessary to prevent further damage, injury or death. Depending on the nature of the incident, Board staff may need to coordinate their efforts with other agencies. Agencies that may become involved in an investigation include the Canadian Coast Guard, Newfoundland and Labrador Department of Government Services, Occupational Health and Safety Branch, the Royal Canadian Mounted Police, the Office of the Chief Medical Examiner, the Transportation Accident Investigation and Safety Board, the Transport Canada Administration (Marine Safety and Aviation Branches), and the Environment Canada Administration.

C-NLOPB
During a C-NLOPB investigation, officers will review the causation of and factors contributing to the incident or suspected violation. Once an investigation has been completed, a decision will be made concerning the action to be taken. Evidence collected during a C-NLOPB investigation may be used as evidence to support a prosecution. **Risk Data Collection through Work Refusals** Pursuant to legislation, workers on offshore installations have the right to refuse any task, which they believe is dangerous to their health and safety, or the health and safety of another person at the workplace. Where a worker has exercised his or her right to refuse and the matter is not remedied to the satisfaction of the worker the matter shall be brought to the attention of the offshore JOHSC and reported to a C-NLOPB Safety Officer. If the committee is unable to resolve the matter, the matter will be investigated by a Safety Officer who has the authority to order a resolution. A person may refuse the work until either they are satisfied with the remedial action taken by the employer, or a Safety Officer has investigated the matter and has rendered a decision. A worker can report a work refusal either in writing or orally to a Safety Officer. The proper sequence for a worker to exercise this right begins with a formal report of the task being refused to the supervisor with the reason for the refusal. Next, a supervisor is provided with the opportunity to resolve concerns, but if the concern is not remedied by the supervisor to the satisfaction of the worker, then a report to the offshore JOHSC for remediation occurs (the Committee notifies the C-NLOPB at this point that a refusal has occurred). Once the JOHSC is involved, the Committee is provided with the opportunity to resolve concerns, but if a concern is not remedied by the Committee to the satisfaction of the worker, then a C-NLOPB Safety Officer will be requested to investigate the issue. Once a C-NLOPB Safety Officer conducts an investigation and renders a final decision, the employer and/or worker must abide by the decision. Employers, operators and Unions shall not take any reprisal against a worker for exercising his or her right to refuse. The work refusal process is outlined in the “Other Requirements Respecting Occupational Health and Safety” which is a condition of approval for each authorization. **Risk Data Collection through Acquiring An Operating License** Before carrying out any work or activity respecting petroleum operations in the Newfoundland and Labrador Offshore Area, an operator must obtain both an Operating License and an Authorization as specified by Sections 137 and 138 of the *Atlantic Accord Act*. There are also various approvals required for certain activities and matters. A centralized regulatory coordination function has been established within the C-NLOPB to ensure a consistent and timely review of applications for authorizations and approvals. Any individual or corporation may apply for an Operating License by completing and forwarding an Operating License Application form to the Board’s Legal and Land Department. Operating Licenses are issued for a maximum period of one year and are valid from their commencement date to the March 31st following and are not transferable. It is the operator’s responsibility to ensure that these licenses are renewed before they become due in order to continue work in the offshore area. In order to obtain an authorization, the operator must ensure that the statutory and regulatory requirements pertaining to the work or activity are satisfied. These matters pertain to: Safety, Environment, Resource Management, Exploration, Legal and Land, and Industrial Benefits.
ORGANIZATION APPLICATION OF RISK DATA **Use of Risk Data for Development Plan, Authorization Approvals and Strategic Environmental Assessments** When an operator seeks an authorization to carry out work or activity relating to developing a pool or field, a Development Plan must first be approved, unless consent to issue the authorization is otherwise granted by both the provincial and Federal governments. Exploration activities and other activities that do not involve development activities can be carried out without a Development Plan Approval. There three types of authorizations administered by the C-NLOPB include: Operations Authorization; Geophysical Program Authorization, and; Diving Program Authorization. Approvals may involve the approval of certain documents, plans or other matters as specified by legislation or

C-NLOPB
regulations, or the approval of specific activities conducted under an authorization. Approvals include: Development Plan Approval; Approval of a Canada-Newfoundland and Labrador Benefits Plan; Approval of Flow System and Flow Calculation and Allocation Procedures; Approval to Commingle Production; Approval to Drill a Well; Approval to Alter the Condition of a Well, and; Approval of a Formation Flow Testing Program. An Approval to Drill a Well (ADW) or an Approval to Alter the Condition of a Well (ACW) is required for well operations involving drilling a well or that involves re-entering a well following completion of the scope of activities covered by the ADW, respectively. A well site seabed survey must be completed prior to the issuance of the ADW. Information regarding the process for obtaining approval of well site surveys is provided under the Geophysical Program Authorization (GPA). In addition, the C-NLOPB) undertakes an environmental assessment of petroleum exploration and production works or activities proposed within the Newfoundland and Labrador Offshore Area. In particular, a Strategic Environmental Assessment (SEA) is performed, which is a broad-based approach to environmental assessment that examines the environmental effects which may be associated with a plan, program or policy proposal and that allows for the incorporation of environmental considerations at the earliest stages of program planning. SEA's typically involve a broader-scale environmental assessment (EA) that considers the larger ecological setting, rather than a project-specific environmental assessment that focuses on site-specific issues with defined boundaries. The C-NLOPB decided in 2002 to conduct an SEA of portions of the Newfoundland and Labrador Offshore Area that may have the potential for offshore oil and gas exploration activity but that were not subject to recent SEA nor to recent and substantial site-specific assessments.
References • C-NLOPB Safety Legislation and Guidance: http://www.cnlopb.ca/safe_leg.shtml • C-NLOPB Safety Compliance and Enforcement: http://www.cnlopb.ca/safe_compliance.shtml C-NLOPB Safety Assessment: http://www.cnlopb.ca/safe_assess.shtml • C-NLOPB Drilling and Production Regulations: http://www.cnlopb.ca/pdfs/regulations/drillprodregs.pdf • C-NLOPB Regulatory Equivalencies: http://www.cnlopb.ca/leg_equiv.shtml • C-NLOPB Petroleum Authorization & Approvals: http://www.cnlopb.ca/ap_authorization.shtml • C-NLOPB Approval Forms: http://www.cnlopb.ca/ap_approval.shtml • C-NLOPB Completed SEAs: http://www.cnlopb.ca/environment/lsseac.shtml • C-NLOPB Other Requirements Respecting Occupational Health and Safety: http://www.cnlopb.ca/pdfs/reqosh.pdf

F.4. CNH

Table F4 provides detailed information about CNH.

Table F4. Agency Overview for CNH

CNH	
Country of Origin	Mexico
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	**Presiding Commissioner of CNH**, Juan Carlos Zepeda Molina zepedajuancarlos@cnh.gob.mx Telephone: +52 (55) 1454-8500 **General Director of Planning**, Oscar Jaime Flores Roldán oscar.roldan@cnh.gob.mx Telephone: +52 (55) 1454-8565

CNH	
	General Director of Development, Gaspar Hernandez Franco gaspar.franco@cnh.gob.mx Telephone: +52 (55) 1454-8531 **Executive Secretary of CNH**, Carla Gabriela Rodriquez Gonzalez gabriela.gonzalez@cnh.gob.mx Telephone: +52 (55) 1454-8554

HISTORICAL BACKGROUND/SUMMARY OF MISSION:

In order to meet the great challenges of the hydrocarbon exploration and extraction industry, and to ensure the country's medium and long term energy security, on April 8, 2008, the Federal Government of Mexico introduced a package of reform initiatives and proposals for the creation of several agencies concerning the oil, gas and energy sector. A proposal was made for the creation of a de-centralized agency within the Ministry of Energy that would be provided with technical and operational autonomy. This new agency, within this packaged proposal, would act as a necessary support organization to the Ministry in order to strengthen the State as the highest and only authority in the oil industry.

In this regard, on November 28, 2008, the National Hydrocarbons Commission Law was published in the Official Federal Gazette, by virtue of which the Mexican Congress had just established the National Hydrocarbons Commission, or CNH. Similarly, the CNH's existence and powers were acknowledged in different arrangements such as the Organic Law of Federal Public Administration and the Regulatory Law of Constitutional Article 27 in the Petroleum Sector.

CNH was formally installed on May 20, 2009 by means of the presidential appointment of five commissioners, members of its governing body, which included Mr. Juan Carlos Zepeda Molina as President Commissioner and as Commissioners; Dr. Edgar René Rangel Germán, Mr. Javier Humberto Estrada Estrada, Dr. Guillermo Cruz Domínguez and Mr. Eduardo Alfredo Guzmán Baldizán. Due to this new institutional arrangement, the Mexican Federal Government, through CNH, now has an agency with technical autonomy to regulate and supervise the exploration and exploitation of Mexico's energy reserves.

CNH Objective and Mission

The National Hydrocarbons Commission's fundamental objective is to regulate and supervise the exploration and extraction of hydrocarbons/energy reserves, in beds or reservoirs, in whatever their physical state, including their intermediate states. This energy component mission consists of the extraction of crude mineral oil, associated with it or result from it, as well as processing activities, transportation and storage directly related to exploration and production projects.

To achieve its goal, CNH carries out its duties, ensuring that the exploration and exploitation projects of "Petroeos Mexicanos", or Mexican Petroleum (PEMEX), and its subsidiary companies are performed. In particular, Article 3 of the CNH Law establishes that the Commission must oversee that PEMEX's Exploration and Production (E&P) projects are carried out pursuant to the following bases:

I. To increase the recovery factor and obtain the maximum volume of crude oil and natural gas in the long term (in economically viable conditions for wells, fields and abandoned reservoirs, or in process of abandonment or exploitation).
II. The replacement of hydrocarbon reserves, as a guarantee of Mexico's energy security and according to prospective resources, based on available technology and in-line with the economic viability of projects.
III. The use of appropriate technology for exploration and extraction of hydrocarbons, in terms of production and economic results.
IV. Environmental protection and sustainability of natural resources during hydrocarbon exploration and exploitation.

CNH

V. Conduct exploration and extraction of hydrocarbons taking care of necessary conditions for industrial safety.
VI. Minimizing flaring and venting of gas and hydrocarbons during their extraction.

CNH established a hydrocarbon policy definition to achieve its mission and goals. The policy definition outlining CNH activities look at, and includes; technical elements to the design of the policy, defining technical regulation for energy E&P projects, hydrocarbon policy implementation, technical assessment for E&P projects, supervision of regulation observance, and, approving hydrocarbon's reserves within the country

CNH Approach to Oil and Energy Regulation

There are three types of approaches when it comes to Energy Regulation and agency protocols; prescriptive, performance and a hybrid based approach. The prescriptive approach directs oil and gas activities through detailed regulations and requirements. Current regulators that impose technical standards in this approach include: Brazil, the United States (US), China, Indonesia and Malaysia.

The performance-based approach requires regulators to get fully involved in each project. It is a case by case assessment whereby operators have to be more proactive in the design of their projects. Current regulators that adopt this approach include: Norway, the United Kingdom (UK), Australia and Canada. At the end of the 1980's, in particular, countries like Norway and the UK had begun to move from a prescriptive to a performance based approach.

Some regulators adopt a hybrid approach by being prescriptive in areas deemed critical, while also establishing broad performance based parameters where the industry needs to meet particular objectives. CNH is among these regulators that have established a hybrid of prescriptive and performance based regulatory approach to E&P. The Commission's hybrid approach of prescriptive and performance-based systems gives greater weight given to the latter. It is based on a three-tier strategy:

I. Revision of PEMEX's internal standards
II. Design of specific technical regulation
III. Technical assessment of E&P projects

ORGANIZATION COLLECTION METHODS OF RISK DATA (RISK INVENTORIES, RISK REGISTERS, TOLERANCE AND ACCEPTANCE LEVELS)

CNH regulation is complemented with supervision, inspections (and drilling permits, when required). In addition, CNH must also establish an Oil Registry/Record that will contain its resolutions and agreements, all opinions, standards and regulations issued among other things. Every E&P project has to be submitted to CNH for a Technical Assessment prior to the issuance of a license by the Ministry of Energy.

The main items considered in a CNH Technical Assessment include; attaining maximum recovery rate under economically viable conditions (with an overall evaluation of alternative technologies) and, looking at the overall security and environment of the E&P area being evaluated for drilling. When looking at the overall security and environment, CNH focuses in on minimizing the flaring and venting of gas, performing a comprehensive risk assessment (identifying and evaluating various safety risks), preparing contingency plans and demonstrating proof of financial responsibility.

In regards to specific regulatory elements under study for these CNH Technical Assessments, CNH looks at; Technical Aspects, Procedures and Management protocol. In regards to technical aspects, CNH has looked at the introduction of double shear ram in blowout preventers. In regards to procedures, CNH looks at third party verification in BOPs and emergency systems as well as double-key authorization in critical procedures. Finally, in regards to Management, CNH looks at requirements to estimate and control worst-case oil spill discharge volumes

Recently, together with Mexico's Ministry of Energy, CNH moved forward the deadline by which PEMEX has to submit its deep water projects for a Technical Assessment. By doing these detailed Technical Assessment projects,

CNH
CNH is able to characterize all the oil and gas resources of the country, have solid support to define strategies for the National Hydrocarbons policy, and analyze if PEMEX has identified and assessed all relevant risks. If so, then CNH certifies that PEMEX has created the appropriate procedures to respond to accidents and emergencies. If not, CNH is tasked to help them identify and create appropriate procedures. As a result of these assessments, CNH becomes the sole authority to set technical regulations according to the real circumstances of the E&P projects. Prior to execution, E&P projects ***must*** have the four following approvals and statements: I. Verification of consistency with Hydrocarbon policy. II. Alignment with Pemex's Business Plan and Investment Portfolio. III. Favorable technical sanction, performed through the Technical Assessment, of the CNH. IV. Secretary of Energy's approval.
ORGANIZATION APPLICATION OF RISK DATA CNH has applied its findings through compiling its Technical Assessments to establishing criteria for all Heavy Oil Projects. Elements for these projects must include the following (whereby only the best projects meeting these criteria elements, will be carried out): I. Identification of the main alternatives. II. Evaluation of the main alternatives. III. Project Development Plan. IV. Geological, geophysical and engineering aspects: a.) Geology, seismology, petro-physics, volu-metrics, PVT studies, pressure-production testing, fluids chemistry, production mechanisms and models. b) Recovery factors and production profiles. c) Improved Oil Recovery (IOR)/ Enhanced Oil Recovery (EOR) processes: These may be applied to economically increase the cumulative volume of oil that is ultimately recovered from the reservoir at an accelerated rate. It may also be applied to mobilize and recover that percentage of residual oil that cannot be captured by water-flooding alone, or by the use of physical, mechanical, or procedural processes. V. Development and production strategy: a.) Development Plan, b.) Reserves and production forecasts, c.) Drilling and production facilities, d.) Processing facilities. VI. Economic evaluation and risks analysis. VII. Metering. VIII. Gas utilization program. IX. Industrial safety and environment. X. Abandonment. Mexico's now has 6 top new extra Heavy Oil Fields in the NE marine region, which have met the above criteria elements. They account for nearly 12 Billion (BPCE) in revenue and have a certified proved reserve close to 600 million (BPCE). Their development plans are considered to have very conservative recovery factors, whereby IOR/EOR methods will be the only way to considerably increase the recovery factor. These Heavy Oil Fields also have access to advanced technology, which allows geographic location to not be a problem, as they are neighbors with the Ku-Maloob-Zaap Oil Field, the most productive offshore oil field/station in Mexico (producing, as of 2012, 867,000 barrels of oil per day). CNH, in recent years, has applied data collection from its assessments to their Petroleum Regulation standards which now include; technical guidelines for the design of E&P projects, regulation to reduce the flaring and venting of natural gas, security procedures and standards in exploration and exploitation in offshore deep-water oil projects, guidelines to evaluate and determine the hydrocarbons reserves of Mexico, metering of oil and gas,

CNH
security procedures and standards in exploration and exploitation in shallow waters and onshore, and guidelines to determine other prospective resources in Mexico.
References • CNH Background: http://www.cnh.gob.mx/portal/Default.aspx?id=1100 • CNH Petroleum Regulations: http://www.cnh.gob.mx/_docs/Reglamentos/5_Reg_LRArt27_RP.pdf • CNH Natural Gas Report: http://www.cnh.gob.mx/_docs/Reporte_de_volumen_de_petroleo_crudo_derramado_y_fugas_de_gas_natural_I_2014.pdf • CNH Presentation on Regulation Approach: http://www.cnh.gob.mx/_docs/2010_Juan_Carlos_Zepeda_Regulacion.pdf • CNH Presentation to Canada on Heavy Oil Production: http://www.cnh.gob.mx/_docs/CNH_WHOC_March_2011_FINAL.pdf • CNH Presentation to Houston, TX on E&P Industry Regulation: http://www.cnh.gob.mx/_docs/Houston_CNH_JCZ_final_ORF.pdf • CNH Presentation to Mexican Energy Conference on E&P Advances in Deepwater Oil Production: http://www.cnh.gob.mx/_docs/PLATTS%2009112010.pdf • CNH Oil Registry/Record: http://www.cnh.gob.mx/portal/Default.aspx?id=16400 • PEMEX: http://www.pemex.com/Paginas/default.aspx#.VEabJiLF87M

F.5. DEA

Table F5 provides detailed information about DEA, also known as Energistyrelsen.

Table F5. Agency Overview for DEA

DEA	
Country of Origin	Denmark
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	**Director General**, Morten Bæk MB@ens.dk Telephone: + (45) 3392-6666 **Deputy Director General**, Kristoffer Böttzauw krb@ens.dk Telephone: + (45) 3392-6667 **Executive Assistant/Receptionist**, Bente Bruun bbr@ens.dk Telephone: + (45) 3392-7529 **Health, Safety and Environment Engineer**, Christian Saxer csax@ens.dk Telephone: + (45) 3392-6686 **Risk Engineer**, Hans Chr. Langager hcl@ens.dk Telephone: +(45) 3395-4393 **Risk Engineer**, Lars Møller lm@ens.dk Telephone: +(45) 3392-6658

DEA

HISTORICAL BACKGROUND/SUMMARY OF MISSION:

The Danish Energy Agency (DEA), also known as 'Energistyrelsen', was established in 1976, and is under the auspices of Denmark's Ministry of Climate, Energy and Buildings and employs about 300 individuals. The work of the DEA involves matters relating to energy supply and consumption, as well as Danish efforts to reduce carbon emissions. The DEA is also responsible for Danish building policy and promotes more sustainable building with regard to energy consumption, use of materials and economic issues. The first exploration license in Denmark was granted in 1935. Since then there has been robust oil and gas exploration. In 1966 A.P.Møller, with the first well in the Danish part of the North Sea for the first time, discovered hydrocarbons in Denmark. The discovery was also the first find in the North Sea. The exploration continued and a series of oil and gas fields were found. In 1972 the first oil was produced from the Dan field. Since 1983, areas in the North Sea have been offered to interested oil companies in a system of rounds. Six licensing rounds have been held, the latest occurring in 2005 and 2006.

The DEA is responsible for the entire chain of tasks linked to energy production and supply, transportation and consumption, including energy efficiency and savings as well as Danish national CO2 targets and initiatives to limit emissions of greenhouse gasses. DEA supports building-policy initiatives to increase the productivity and quality of building as well as the operation and maintenance of buildings, with focus on sustainable building. It also collaborates with the building sector to establish a good framework for the industry.

In addition, DEA is the sole responsible authority for health and safety on offshore oil installations. Offshore installations are understood as systems for exploration and production of oil and gas from beneath the seabed. Wind farms at sea, however, are excluded from this definition. In regards to security, this includes the built-in safety systems and equipment as well as safety in the workplace and at work. In regards to health, this includes health conditions in the work environment and other health conditions, which also includes workers staying at the installations outside work hours. However, offshore installations are not covered by the Working Environment Act and is, thus not within the scope of Danish Working Environment Authority's responsibility.

In addition to the DEA's other authorities include responsibility for the Offshore Security Council which is the particular entity that oversees the safety, health and environment on offshore installations. The Offshore Safety Council consists of representatives of the social partners and various authorities of the DEA. The Offshore Security Council is established pursuant to section 58 of the Offshore Safety Act for offshore installations for exploration production and transportation of hydrocarbons (Offshore Safety Act). The council has the task of assisting in the drafting of regulations under the Act, to follow the technical and social development on offshore installations and to discuss other matters covered by the Act.

DEA Oil and Gas Field Production Development Responsibility

There are many oil and gas production fields in Denmark, whereby the field operators report how much oil, gas and water is produced from each field to the DEA. The production from the Danish fields was, in 2012, led from the reservoir layers via 278 wells to production facilities. At the same time water and/or gas was injected into 106 wells to increase production. The annual report title, "Denmark's Oil and Gas Production and Subsoil Use," describes among other things the production from the Danish fields.

Applications concerning field development plans are processed according to Danish Law and published in national newspapers. The applications concerning development of oil and gas fields in Denmark are processed by DEA according to §10 in the Danish Subsoil Act. A development application must be accompanied by or relate to a report handling the Environmental Impact Assessment (EIA). Once a decision has been made by the DEA, information about the decision must be published in national newspapers. The public comment period is four weeks.

Any party having a substantial and individual interest in the decision may file an appeal with the Energy Board of Appeals against the environmental issues relating to any such decision.

DEA
An approved application cannot be used before the public comment period of four weeks has passed. Production from the Danish North Sea oil fields has now reached a stage where secondary recovery methods (mainly water injection) are the main drivers of today's oil production. When these secondary recovery methods are no longer profitable, there may still be 70% of the discovered oil left in the fields. This is why the North Sea Fund, the Danish Energy Authority and Mærsk Olie og Gas (AS) have jointly prepared an independent assessment of the existing worldwide experience with different methods to recover more oil from the fields - EOR (Enhanced Oil Recovery). Carbon Capture and Sequestration/Enhanced Oil Recovery (CCS/EOR). CCS/EOR describes a system based on capture from point sources such as power plants and injected in oil fields. The assessment of the existing worldwide experience with different methods to recover more oil demonstrates that the best way to substantially increase oil production from the largest Danish fields is to inject CO2 into the fields. Amongst others, this is the reason that DEA has commissioned a report that describes the socio-economy for a CCS/EOR system in Denmark based on CO2 capture from Danish heat and power plants and injected into Danish oil fields. **Danish Oil Fields: The South Arne Field** South Arne is an integrated installation operated by Hess Denmark ApS. The South Arne platform comprises a combined wellhead, processing and accommodation platform with an oil storage tank on the seabed and buoy loading facilities for oil. The processing facilities consist of a plant that separates the hydrocarbons produced as well as facilities for processing the oil, gas and water produced. The platform also houses equipment for water injection. In order to prevent the depositing of sparingly soluble salts in and around the injection wells, the seawater injected into the field is pre-processed. Thus, the sulphate ions are removed from the seawater prior to injection. The bulk of the produced water is injected into the reservoir. The oil produced is conveyed to an 87,000 m3 storage tank on the seabed. When the tank is full, the oil is transferred to a tanker by means of buoy loading facilities. The gas produced is transported through a gas pipeline to Nybro on the west coast of Jutland. The South Arne Field also has accommodation facilities for 57 persons. **Danish Oil Fields: The Dan Centre** The Dan Centre consists of the installations at Dan, Kraka, Regnar and Halfdan. The Dan Field comprises five wellhead platforms, DA, DD, DFA, DFB and DFE, a combined wellhead and processing platform, DFF, a processing platform, DFG, two processing and accommodation platforms, DB and DFC, and two gas flare stacks, DC and DFD. The Dan DA, DB, DC and DD platform complex is located about 3 km from the Dan F platforms, while Dan E is an unmanned satellite platform ½ km from Dan F. At the Dan Field, there are receiving facilities for the production from the adjacent Kraka and Regnar satellite fields. The Dan Field installations also provide the Halfdan Field with injection water. After final processing, the oil is transported to shore via the riser platform, Gorm E. The gas is pre-processed at Dan F and transported to Tyra East for final processing. Treated production water from Dan and its satellite fields is discharged into the sea. In the Dan Field, there are accommodation facilities for 97 persons on the DFC platform and 5 persons on the DB platform. The Kraka Field is a satellite development to the Dan Field, with an unmanned wellhead platform of the STAR type without a helideck. The produced oil and gas are transported to the Dan F installation for processing and export ashore. Lift gas is imported from the Dan FF platform. The Regnar Field has been developed as a satellite to the Dan Field. Production takes place in a subsea-completed well. The hydrocarbons produced are conveyed by pipeline in multiphase flow to Dan F for processing and export ashore. The well is remotely monitored and controlled from the Dan FC platform. The Halfdan Field comprises a combined wellhead and processing platform, HDA, one accommodation platform, HDB, one gas flare stack, HDC, and an unmanned satellite wellhead platform, HBA, without a helideck.

DEA

The Halfdan Field receives production from the Sif and Igor gas accumulations through special installations on the HBA platform. The HBA satellite platform is located about 2 km from the other Halfdan platforms, which provide it with electricity, injection water and lift gas. Production from the oil wells at HBA is conveyed through a multiphase pipeline for processing at the HDA platform, while production from the Sif/Igor gas wells is separated by a two-phase separator into a liquid and a gas flow. The liquid is piped through the multiphase pipeline to the HDA platform for processing. After separation at the HDA platform, the oil/condensate is transported to Gorm for final processing and export ashore.

Danish Oil Fields: The Gorm Centre

The Gorm Centre consists of the installations at Gorm, Skjold, Rolf and Dagmar. The Gorm Field consists of two wellhead platforms, Gorm A and B, one combined wellhead and processing platform, Gorm F, one processing and accommodation platform, Gorm C, one gas flare stack, Gorm D, and one riser platform, Gorm E (owned by DONG Olierør A/S). Gorm receives production from the satellite fields, Skjold, Rolf and Dagmar, as well as the oil and condensate produced in the Dan, Tyra and Halfdan Fields. The Gorm Field installations supply the Skjold Field with injection water and lift gas and the Rolf Field with electricity and lift gas. The gas produced is sent to Tyra East. The stabilized crude oil is transported ashore via the Gorm E riser platform. There are accommodation facilities on the Gorm C platform for 98 persons.

The Skjold Field comprises a satellite development to the Gorm Field, including two wellhead platforms, Skjold A and B, as well as an accommodation platform, Skjold C. There are no processing facilities at the Skjold Field, and the production is transported to the Gorm F platform in the Gorm Field for processing. The Gorm facilities provide the Skjold Field with injection water and lift gas. The Rolf Field is a satellite development to the Gorm Field with an unmanned wellhead platform, which is provided with a helideck. The production is transported to the Gorm C platform in the Gorm Field for processing. Rolf is also supplied with electricity and lift gas from the Gorm Field. Finally, the Dagmar Field is a satellite development to Gorm including one unmanned wellhead platform of the STAR type without a helideck. The unprocessed production is transported to the Gorm F platform in the Gorm Field, where special facilities for handling the sour gas from the Dagmar Field have been installed. The small amount of gas produced from Dagmar is flared due to the high content of hydrogen sulphide.

Danish Oil Fields: The Siri Centre

The Siri Centre consists of the installations at the Siri platform, including oil storage tanks on the seabed and the buoy loading facilities for oil, as well as the Nini and Cecilie satellite fields and subsea installations at Stine segment. The Siri platform is a combined wellhead, processing and accommodation platform. The processing facilities consist of a plant that separates the hydrocarbons produced and a plant for processing the water produced. The platform also houses equipment for co-injecting gas and water. The Siri platform is a combined wellhead, processing and accommodation platform. The processing facilities consist of a plant that separates the hydrocarbons produced and a plant for processing the water produced. The platform also houses equipment for co-injecting gas and water. The oil produced is conveyed to a 50,000 m3 storage tank on the seabed. When the tank is full, buoy loading facilities are used to transfer the oil to a tanker. The Siri Field has accommodation facilities for 60 persons.

The Nini Field is a satellite development to the Siri Field with one unmanned wellhead platform, which is provided with a helideck. The unprocessed production is transported to the Siri platform where the oil produced is processed and exported to shore via tanker. The gas produced at the Nini Field is injected into the Siri Field together with injection water, and Siri supplies Nini with injection water and lift gas. The Cecilie Field is a satellite development to the Siri Field with one unmanned wellhead platform, which is provided with a helideck. The unprocessed production is transported to the Siri platform where the oil produced is processed and exported to shore via tanker. The gas produced at the Cecilie Field is injected into the Siri Field together with injection water, and Siri supplies Cecilie with injection water and lift gas.

DEA
Danish Oil Fields: The Tyra Centre The Tyra Centre consists of the installations at Tyra, Roar, Valdemar, Tyra Southeast, Svend and Harald/Lulita. The Harald installations, which process production from Harald and Lulita, also form part of the Tyra Centre. The Tyra Field installations comprise two platform complexes, Tyra West (TW) and Tyra East (TE). Tyra West consists of two wellhead platforms, TWB and TWC, one processing and accommodation platform, TWA, and one gas flare stack, TWD, as well as a bridge module installed at TWB and supported by a four-legged jacket, TWE. The Tyra West processing facilities include plant for pre-processing oil and condensate production from the wells at Tyra West. Moreover, the Tyra West complex houses facilities for the injection and/or export of gas and processing facilities for the water produced. Oil and condensate are transported to Tyra East for final processing. Tyra has wellhead compression facilities to which the Tyra oil wells and satellite wells, including Harald, are connected. Tyra East consists of two wellhead platforms, TEB and TEC, one processing and accommodation platform, TEA, one gas flare stack, TED, and one riser platform, TEE, as well as a bridge module supported by a STAR jacket, TEF.Tyra East receives production from the satellite fields, Roar, Svend, Tyra Southeast and Harald/Lulita, as well as gas production from the Gorm and Dan/Halfdan Fields and liquids from Valdemar. The Tyra East complex includes facilities for the final processing of gas, oil, condensate and water. Tyra West receives the gas produced in the Valdemar and the Halfdan NE/Halfdan satellite fields. The Tyra West complex includes facilities for the final processing of gas and water. Oil and condensate are transported to Tyra East for final processing. The two platform complexes in the Tyra Field are interconnected by pipelines in order to generate the maximum operational flexibility and reliability of supply. Oil and condensate production from the Tyra Field and its satellite fields is transported ashore via Gorm E, while the gas produced is transported from TEE at Tyra East to Nybro on the west coast of Jutland and from TWE at Tyra West to the NOGAT pipeline for export ashore in the Netherlands. The development plan of the Halfdan Field (Igor) approved in June 2006 comprises an increase of the wellhead compression capacity at Tyra West. The new capacity makes it possible to operate the Halfdan gas wells at a low wellhead pressure maintaining the service to the oil wells in the Tyra Field and all wells at Harald, Roar, Valdemar and Tyra Southeast. The Roar Field has been developed as a satellite to the Tyra Field with an unmanned wellhead platform of the STAR type without a helideck. After separation into a gas and a liquid phase, the hydrocarbons produced are conveyed through two pipelines to Tyra East for processing and export ashore. The Valdemar Field has been developed comprising two satellite installations to Tyra, Valdemar A and Valdemar B. Valdemar A comprises two unmanned wellhead platforms (VAA and VAB) of the STAR type without a helideck, connected by a bridge. After separation the production of gas is transported to Tyra West for processing and transportation ashore/export, while the liquid production (oil and water) is transported to Tyra East for processing and export ashore. Valdemar B comprises an unmanned wellhead platform (VBA) of the STAR type without a helideck, some 4 km from the Valdemar VAA/VAB complex. The production from Valdemar VBA is conveyed to the Roar installations through a multiphase pipeline which on the seafloor is tied in to the gas pipeline between Roar and Tyra East. The production from the Valdemar VBA platform is transported to Tyra East for processing and export ashore. The Tyra Southeast Field has been developed as a satellite to Tyra, including an unmanned wellhead platform of the STAR type without a helideck. After separation into a gas and a liquid phase, the production is transported to Tyra East in two pipelines to be processed and subsequently exported ashore. The Svend Field, situated about 65 km north of the Tyra Field, has been developed as a satellite to the Tyra Field, with an unmanned STAR platform without a helideck. The hydrocarbons produced are conveyed to Tyra East for processing and export ashore. The Svend Field is connected to the 16" multiphase pipeline from Harald to Tyra East. The Harald Field, situated about 80 km north of the Tyra Field, comprises a combined wellhead and processing platform, Harald A, and an accommodation platform, Harald B. The processing facilities consist of a plant that

DEA

separates the hydrocarbons produced at Harald and Lulita, as well as a plant for the final processing of the gas produced. The production of oil and condensate and the processed gas are transported to Tyra East. Treated water from the Harald and Lulita Fields is discharged into the sea from Harald A. The Harald Field is hooked up to the gas pipeline that conveys gas from the South Arne Field to Nybro. Normally, no gas is exported from Harald through the pipeline. The Harald B platform has accommodation facilities for 16 persons.

The Lulita Field production takes place from the fixed installations in the Harald Field. Thus, the Lulita wellheads are hosted by the Harald A platform, and the Harald platform facilities also handle production from the Lulita Field. Together with the condensate produced at the Harald Field, the Lulita oil is conveyed through a 16" pipeline to Tyra East for processing and then exported ashore. The gas produced in the Lulita Field as well as the Harald Field is transported to Tyra East through the DONG-owned gas pipeline connecting Harald with Tyra East, from where it is transported to shore.

ORGANIZATION COLLECTION METHODS OF RISK DATA (RISK INVENTORIES, RISK REGISTERS, TOLERANCE AND ACCEPTANCE LEVELS)

DEA Risk Assessments

The main principle of Denmark's Offshore Safety Act is that the health and safety risks to persons working and staying on an offshore installation shall be identified, assessed and reduced as much as is reasonably practicable. The results from this review shall be documented in a *Risk Assessment*, which will cover the following concerns to DEA:

- Major hazards (fire, explosion, collisions, helicopter accidents, falling objects, etc.).
- Risks in the work environment (physical, chemical and biological conditions and accident risks)
- Risks by staying at the facility (hygiene, drinking water and water quality, indoor air quality of the accommodation and the impact of tobacco smoke, etc.).
- *As Low As Reasonably Practical (ALARP) Assessment* (i.e. that risks shall be reduced to a level that is as low as reasonably practicable).

For the fixed offshore installations that DEA oversees, the safety and health risks are identified, assessed and minimized at all stages of the life of the installation, i.e. in the design, construction, delivery, installation, operation and changes to the system. The similar applies for Mobile Offshore Drilling Units (MODUs). The responsible company will, in practice, be the operator on fixed offshore installations, while on mobile offshore units it will be the company which contracted with the operator.

Risks with Design, Construction & Delivery/Installation of Fixed Offshore Installations

The risk assessment for fixed installations starts in the project phase where the operator, through the design and layout of the facility, aims to reduce the health and safety risks as much as is technically possible and economically viable. In the design phase the risk assessment is an overall assessment based on the present knowledge of the project. Subsequently the risk assessment is updated as the detail of the project is determined. An assessment of the risk of major hazards is in accordance with recognized methods for risk assessment.

An assessment of risks in the work environment typically includes: Physical conditions: e.g. the work room, the surroundings, noise, indoor air quality, vibration and lighting; Ergonomic factors: e.g. heavy work, repetitive work and posture; Psychological factors: e.g. working hours, time pressure, monotony, influence, violence and working alone; Chemical factors: e.g. work with substances and materials; Biological conditions: e.g. bacteria, viruses and fungi, and; Risks of accidents: e.g. from machinery, hand tools, traffic, handling of items, fire and explosion.

There are certain considerations that should be given to these risks in the design of new facilities and modifications to existing facilities after the ALARP principle. In particular, for the operations of fixed offshore installations as well as its modification, the operating company shall make an assessment of the health and safety risks associated with the operation of the offshore installation and reduce them as much as is reasonably practicable.

DEA

When a risk assessment is formed by DEA, they are made available before the plant is brought into service. Risks of the operation is all risks the workers are exposed to from the time they meet in the airport or shipping port, which transfers them to the offshore installation until they are back on shore again. These risks can be:

- Risks of transport by helicopter or by sea between the facility and shore and transport between different offshore installations.
- Risks arising from the construction of the installation.
- Risks associated with work and stay at the facility during the non-working hours.
- Risks arising from the interaction between several offshore installations, for example the combination of mobile drilling rigs and fixed installations.

The operating company shall constantly seek to improve safety and health through continued reduction of the health and safety risks. The risk assessment should be updated when significant changes are made by the plant, for example, by extension of platforms, expanding the number of wells, purchase of new equipment, etc. When updating the installation the ALARP principle shall be applied again for the changed conditions.

When working at the offshore installation the individual employer shall make sure that the safety and health risks are identified assessed and reduced as much as is reasonably practicable before the work starts. This can be done through a work permit system. The operating company shall also make an assessment of the health and safety risks associated with the operation of the mobile unit and reduce them as much as is reasonably practicable. All risk assessments shall be done before the unit is put into operation.

DEA risk assessments of mobile offshore units can be prepared according to "International Guidelines of Drilling Contractors, Health, Safety and Environmental Case (Guidelines for Mobile Offshore Drilling Units)". The operator is to ensure that the mobile unit and its working environment are fully safe and healthy. Valid certificates issued by the flag state and a recognized classification company on behalf, thereof, may constitute evidence that the parts of the mobile unit which is covered by the certificates is safe. If there are significant changes on a mobile offshore unit or on the operational conditions while it is in operation in the Danish sector the operator is obliged to update the risk assessment.

DEA Evacuation Analysis

An evacuation analysis shall demonstrate that the staff on an offshore installation in critical situations can be evacuated to a safe place in an efficient and controlled manner. Evacuation analysis shall, as a minimum, describe situations where evacuation of the offshore installation will be necessary (These situations shall be determined on the basis of the completed risk assessment of major hazards). In addition, they describe and assess escape routes, evacuation options and safe places that can be used under evacuation. In addition, they assess the risk that persons cannot be evacuated to a safe place and demonstrate that risks are reduced as much as is reasonably practicable

DEA Health and Safety Case

A Health and Safety Case must demonstrate that the health and safety risks on the offshore facility are identified, assessed and reduced to a level that is as low as is reasonably practicable (ALARP). A health and Safety Case must also prove that the company can manage these risks in a controlled manner and, if necessary, evacuate the plant in an efficient and controlled manner in critical situations.

The health and Safety Case must be updated whenever there are significant changes in the safety and health conditions or operational conditions on the installation. For mobile offshore units, the health and safety report can be prepared in accordance with the, "International Guidelines of Drilling Contractors, Health, Safety and Environmental Case (Guidelines for Mobile Offshore Drilling Units)." A Health and Safety Case does not have to be a single coherent document containing the above information, but must at least refer to where the different parts can be found.

DEA
The minimum requirements for DEA Health and Safety reports include a detailed description of the offshore installation and its operating conditions as well as a detailed description of the management system for safety and health. Also include is an identification of the risks of major hazards and adverse impact on the working environment by staying at the facility. In addition, an assessment of risks and evidence is provided as well as an assessment that these risks are reduced as much as is reasonably practicable (ALARP). Finally, documentation is provided validating that evacuation to a safe place can take place in an efficient and controlled manner in critical situations.

ORGANIZATION APPLICATION OF RISK DATA

Risk Data Used to Report Injuries, near misses, etc.
Injuries resulting in incapacity for more than 1 day shall are to be reported to the DEA. An injury is understood as damages caused to persons either by an accident on the offshore installation or an illness occurred through prolonged exposure of harmful factors during work or stay at the offshore installation (i.e. Chemicals, noise and body loads). Near miss incidents are understood as an event that could have directly led to an accident or damage on equipment.

The operating company has a duty to report injuries and risk, in accordance with §3 of Executive Order No. 1083 of 5 September 2013 on the Registration and Notification of Occupational Injuries (the Notification Order), pursuant to the Offshore Safety Act. Pursuant to the Offshore Safety Act §4, paragraph 3, the operating company is responsible for the offshore installation and shall register:

1. Any accident or death happened on the offshore installation.
2. Near-miss incidents, including any discharges of oil.
3. Any significant damage to the offshore installation or equipment relating to the health and safety.

The operating company shall also report:

1. Any near miss incident that could have resulted in death or accident involving serious injury or threat of offshore installation integrity.
2. Any escape of hydrocarbons that
   a) resulted in fire or explosion or
   b) had the potential to cause a major hazard within the meaning of the Executive Order on management of health and safety on offshore installations etc.
3. Any incident where a person has been or is likely to have been exposed to ionizing radiation for more than the extent permitted by the rules of dose limits of ionizing radiation set by the Danish Health and Medicines Authority's order on health control at work with ionizing radiation on offshore installations.
4. Any incident that may have resulted in the release of a biological agent, and which may cause serious infections or diseases on humans.
5. Any significant damage to the offshore installations construction or equipment of safety or health.

The liable employer, who has the duty to notify, shall report the following to the DEA pursuant to § 4 of the Notification Order:

1. Accidents resulting in death.
2. Any accident that results in the victim being incapacitated for 1 day or more from the injury date.
   The liable employer is the employer who is required to sign the accident insurance under the Workers' Compensation Act.

The DEA reviews and assesses whether there should be taken some immediate measures. All reported injuries and near misses are reviewed offshore at the next supervision visit. The DEA usually inspects the site of accident in connection with an immediately report, usually with the police. The results of the DEA analysis and follow-up on selected events on Danish offshore installations 2002 - 2008 can be found in the yearly report of "Denmark's Oil

DEA
and Gas Production," whereby the DEA prepares statistics on reported injuries and near misses. This statistic and the individual reviews are included in the DEA's priority of supervision. **Risk Data as Part of Requirements for Documentation - Fixed Offshore Installations** The basic documentation of management of health and safety of a fixed offshore installation is a Health and Safety Case. The basic documentation of management of health and safety of a fixed offshore installation is a Health and Safety Case. The Health and Safety Case shall demonstrate that the duty holder (operator or operating company) has assessed the health and safety risks on the installation and reduced the to a level that is as low as reasonably practicable (ALARP) and also demonstrate that these risks are controlled through a health and management system. Included in the Health and Safety Case is a demonstration that all persons on board, if necessary, can be evacuated to a safe place in a quick and controlled manner. A significant part of the safety documentation for a fixed installation's physical condition is based on compliance with recognized national and international standards and norms, often documented through certification or verification performed by experts recognized by the DEA. Recognized standards related to construction and equipment on the offshore installation, are typically ISO, EN and also API standards. Other standards may be used, for example, Det Norske Veritas (DNV), NORSOK, American Gas Association (AGA) and ASTM. **Risk Data Being Used for Reports on Oil and Gas Activities** The report, "Denmark's Oil and Gas Production and Subsoil Use," gives an overview of the activities in the oil and gas sector and uses of the Danish subsoil other than oil and gas activities as well as summarizes activities of the previous year in the Danish oil and gas sector. The report has been published annually since 1986. Moreover, the report describes the use of the Danish subsoil for purposes other than oil and gas production, focusing on exploration and production of geothermal energy for district heating purposes. In addition, the report contains an assessment of Danish oil and gas reserves and a chapter on the impact of hydrocarbon production on the Danish economy. Within the report are sections on assessing Danish oil and gas reserves, oil and gas production (as well as risk data), the impact of hydrocarbon production on the Danish economy, oil and gas licenses, exploration for hydrocarbons, development of oil fields, oil and gas activities' impact on the environment and climate, natural gas storage and geothermal energy licenses.
References • DEA Risk Assessment: http://www.ens.dk/en/oil-gas/health-safety/risk-assessment-0 • DEA Rules and Guidelines for Offshore Installations: http://www.ens.dk/en/oil-gas/health-safety/rules-guidelines-health-safety-offshore-installations-2 • DEA Rules pursuant to Offshore Safety Act: http://www.ens.dk/en/oil-gas/health-safety/rules-pursuant-offshore-safety-act-2 • DEA Climate and Energy Policy: http://www.ens.dk/en/policy/danish-climate-energy-policy • DEA Oil Well Assessments/Appraisals Database: http://www.ens.dk/en/oil-gas/oil-gas-related-data/wells • DEA Oil and Gas Report Archives: http://www.ens.dk/en/oil-gas/reports-oil-gas-activities

F.6. WorkSafe

Table F6 provides detailed information about WorkSafe.

Table F6. Agency Overview for WorkSafe

WorkSafe	
Country of Origin	New Zealand

WorkSafe	
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	**CEO,** Gordon MacDonald Telephone: 04-897 7699 **General Manager, Program Development,** Tracy Mellor **General Manager, High Hazards & Specialist Services**, Brett Murray **General Manager, Health and Safety Operations,** Ona De Rooy **Business Manager,** Catherine Spiller **General Manager/CFO,** Wayne Verhoeven **General Contact** hhu.petroleum@worksafe.govt.nz

HISTORICAL BACKGROUND/SUMMARY OF MISSION:

WorkSafe is a subagency of the Ministry of Business, Innovation and Employment (MBIE). MBIE was formed as a consolidation of agency functions formerly performed by the Department of Building and Housing, Ministry of Economic Development, Department of Labour, and Ministry of Science and Innovation. Prior to MBIE, most health and safety functions were split between the Ministry of Economic Development and Department of Labour. After the formation of MBIE in July 2012, health and safety and many economic development functions were performed directly by MBIE.

The enactment of the WorkSafe New Zealand Act in 2013 created WorkSafe. The act not only specified the responsibilities of the subagency, but also performance targets. The government had determined that New Zealand faced unacceptable work-related fatality and injury rates (twice as high as Australia's) and made it their objective to achieve a 25% reduction in fatalities and injuries by 2020.

WorkSafe began operations in December 2013. Its creation was a direct response to the Royal Commission of Inquiry into the Pike River Coal Mine Tragedy in 2012 and Independent Taskforce on Workplace Health and Safety in 2013 which recommended an isolation of health and safety regulatory authority in New Zealand from the rest of MBIE's missions. In the process, WorkSafe also inherited responsibility for public electricity and gas infrastructure safety enforcement under the Electricity Act of 1992, the Gas Act of 1992 and some provisions of the Hazardous Substances and New Organisms (HSNO) Act of 1996. Now WorkSafe is the sole regulator of worker safety in NZ.

New Zealand's drilling industry is relatively small, but has been in operation since the 1960's. There are over 200 offshore wells, and only 10 in deep water. WorkSafe monitors seven fixed offshore installations and one MODU, though the government is motivated to expand production. To date, there have been no offshore blow-outs and the largest spill was 23 tons of oil.

Offshore Regulatory Environment

In New Zealand waters, operators are subject to multiple government agencies, each of which covers a different aspect of the petroleum production process. Oversight is not consolidated under one agency. For drilling permits, operators report to New Zealand Petroleum and Minerals (NZP&M). The NZP&M regulates the mining of oil, gas, mineral, and coal resources within New Zealand and ensures that operators have the technical and financial to carry out their intended production plans. The NZP&M also performs a preliminary check of the operator's ability to maintain the health and safety of its workers.

Another regulator with jurisdiction in the offshore environment is the Environmental Protection Authority (EPA). Prior to beginning production, operators must assemble an environmental impact assessment. If the EPA finds the

WorkSafe
assessment satisfactory, they will issue a marine consent. After operations begin, the EPA will continue to monitor and enforce compliance. Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act (2012). Maritime New Zealand (MNZ) requires that operators have established plans for managing production waste and accidental spills. Generally, MNZ is responsible for oil spill response preparedness and coordination. Finally, WorkSafe is responsible for maintaining worker safety. Because well blowouts often endanger workers on the petroleum production rigs, WorkSafe is also enforces well integrity. In this capacity, WorkSafe also has the power to deny permission to operate. WorkSafe maintains a Safety Case regime for its offshore oil and gas operators, as described later in this table. Health and Safety in Employment (Petroleum Exploration and Extraction) regulations (2013). Once NZP&M issues a permit, the EPA, MNZ and WorkSafe all have the power to inspect operations and enforce penalties or revoke licenses for noncompliance. In addition to its collaboration with these other agencies, WorkSafe maintains a working relationship with the New Zealand Police, Civil Aviation Authority, NZ Transport Agency, and Accident Compensation Corporation (ACC) in order to administer its regulatory powers. **Regulatory Activities** WorkSafe is aggressively pursuing its goal of a 25% reduction in injuries by working to educate employees and employers about responsible health and safety behavior, enforcing health and safety legislation, and by encouraging employers to make changes to reduce risk. In a year, WorkSafe's 350 employees carry out over 12,500 assessments of workplace safety, targeting high risk industries such as agriculture, forestry, construction, and manufacturing. They will also carry out 3,500 HSNO workplace assessments; deliver 60 high hazard assessments, inspections, audits and Safety Cases; investigate at least 1,000 incidents; and maintain a continuous risk reporting response center. Besides performing field work, WorkSafe collaborates with industry stakeholders to develop safety standards. These stakeholders include organizations like Business New Zealand and the Council of Trade Unions. WorkSafe is also involved with the Business Leader's Health and Safety Forum—a forum with 100 business and government leaders for the purpose of improving safety. **Regulatory Philosophy** New Zealand has made it its goal that "Everyone who goes to work comes home healthy and safe." In the Offshore environment, WorkSafe is pursuing this goal through risk-based inspection, inspection and enforcement, and collaboration with stakeholders. In these activities, WorkSafe is committed to consistent, transparent, fair, firm, respectful, and courageous legislation. The agency is in charge of producing radical improvements in the health and safety of New Zealand's workers. In WorkSafe's 2014 Statement of Intent, it is stated that "WorkSafe NZ is at the center of the most significant reforms to New Zealand's workplace health and safety system in 20 years." WorkSafe claims a risk-based approach focusing on low frequency, high-consequence accident prevention. As such, even though WorkSafe's responsibilities extend well beyond offshore petroleum operations, the petroleum industry attracts particularly special attention. WorkSafe primarily takes a goal-setting approach to legislation but also includes some prescriptive regulations in its regime. Given the poor safety history in New Zealand, the safety regulator focuses on the future. In its Working Safer Reforms, WorkSafe promotes its own strength and organizational stability, working together with industry, targeting the most significant risks in the nation, and working smarter. Unlike NOPSEMA which implements full cost recovery, WorkSafe is fully government-funded. On the other hand, WorkSafe does maintain similar principles in the petroleum industry to other international regulatory bodies. Work safe does not approve Safety Cases, but simply reviews them and then does not deny permission to operate, as in

WorkSafe
the UK's HSE regime. Similarly to Norway's PSA, WorkSafe does not take responsibility for preventing or recovering from oil spills, but instead requires that industry maintain plans and capabilities for responding to disaster.
ORGANIZATION COLLECTION METHODS OF RISK DATA (RISK INVENTORIES, RISK REGISTERS, TOLERANCE AND ACCEPTANCE LEVELS) WorkSafe is moving toward a risk-data-driven approach in its operations. The results of the study produced by the Independent Taskforce on Workplace Health and Safety in 2013 indicated that New Zealand's health and safety regulations lacked quality data for informing regulation. Since then, WorkSafe has been working to establish a baseline data-driven program which will allow WorkSafe to track changes to the status of health and safety throughout New Zealand. To date, these efforts have at least lead to a better picture of what data are currently available to WorkSafe—though most of it is not specifically geared toward offshore production regulation. WorkSafe's Serious Injury Outcome Indicator data tracks high level trends in work-related injuries. The ACC collects claims data for occupational injuries in New Zealand. ACC's data are not comprehensive since it does not have any data for injuries in which no claim is made. For understanding safety culture within New Zealand business, WorkSafe has a number of surveys that it uses. The National Survey of Employers is a survey of a representative sample of 1500 employers. The NZ Baseline Research surveys employee attitudes and behavior related to health and safety, especially in WorkSafe's priority sectors of agriculture, construction, forestry, manufacturing, and fishing. There are a number of surveys of related issues by other agencies in which WorkSafe is pursuing additional cooperation so that the survey can be modified to include additional health and safety questions. These are the Redevelopment of the Household Labour Force sponsored by Statistics New Zealand and the Survey of Working Life – a survey performed every few years as a supplement to the Redevelopment of the Household Labour Force survey. Finally, WorkSafe has data related to its operations and activities. After performing inspections, WorkSafe requests that the inspected company respond to a survey related to the inspection. WorkSafe also keeps records of all of its prosecutions, enforcement actions, investigations, complaints, and assessments. Many of these initiatives include petroleum activity but are not exclusively related to it. In the offshore petroleum area, WorkSafe has begun a Safety Case Regime, requiring that operators demonstrate that risks are ALARP prior to their beginning production.
ORGANIZATION APPLICATION OF RISK DATA WorkSafe has data from multiple sources, but has not yet acquired enough history of collected data to make much sense of what is happening in the country related to health and safety. The country is in transition. Furthermore, although there may be other data related specifically to WorkSafe's responsibilities in the offshore production environment, WorkSafe's health and safety responsibilities include far more than offshore production, so their data collection and processing efforts are not specifically focused on that industry.

WorkSafe
REFERENCES • IRF WorkSafe Background: http://www.irfoffshoresafety.com/country/NewZealand.aspx • Ministry of Business, Innovation and Employment: http://www.mbie.govt.nz/ • About WorkSafe: http://www.business.govt.nz/worksafe/about • What WorkSafe Does: http://www.business.govt.nz/worksafe/about/what-we-do • History: http://www.business.govt.nz/worksafe/about/who-we-are • Leadership: http://www.business.govt.nz/worksafe/about/who-we-are/leadership-team • Collaboration: http://www.business.govt.nz/worksafe/about/who-we-work-with • WorkSafe Vision & Values: http://www.business.govt.nz/worksafe/about/vision-and-values • Statement of Intent: http://www.business.govt.nz/worksafe/about/publications/documents/statement-of-intent-2014-pdf • Petroleum Health and Safety: http://www.business.govt.nz/worksafe/information-guidance/legal-framework/hse-act-1992/regulations/regulations-extractive-sector/health-and-safety-in-employment-petroleum-exploration-and-extraction-regulations-2013 • High Hazards: http://www.business.govt.nz/worksafe/about/what-we-do/high-hazards/petroleum • Safety Case Submissions: http://www.business.govt.nz/worksafe/about/what-we-do/high-hazards/petroleum/safety-case-submissions • Deep Sea Drilling: http://www.nzpam.govt.nz/cms/iwi-communities/government-role/deep-sea-drilling#manage

F.7. HSE

Table F7 provides detailed information about HSE.

Table F7. Agency Overview for HSE

HSE	
Country of Origin	Great Britain (U.K.)
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	HSE Chair, Judith Hackitt: Judith.Hackitt@hse.gsi.gov.uk Telephone: +44 (0300) 003 1747 HSE Chief Executive, Dr. Richard Judge: Richard.Judge@hse.gsi.gov.uk Telephone: +44 (0300) 003 1747 HSE Policy Lead- Environment, Radiation & Gas, Peter Lennon: peter.lennon@hse.gsi.gov.uk Telephone: +44 (0151) 951 3014 HSE Executive Assistant, Ms. Tori Hywel-Davies: Tori.Hywel-Davies@hse.gsi.gov.uk Telephone: +44 (0783) 340 2620
The HSE traces its history to the U.K.'s Health and Safety at Work Act of 1974, introducing 'Risk' and the 'Duty' of the Employer to manage Risk. The act stated that, "It shall be the duty of every employer to ensure, SFAIRP, the health, safety and welfare at work of all [his/her] employees." SFAIRP and ALARP mean essentially the same thing as at their core is the concept of "reasonably practicable," which involves weighing a risk against the resources needed to control it. In 2001, U.K. HSE instituted an initiative known as R2P2. This defined "Tolerable" vs. "Intolerable" Risks, looking at society's outlook towards Risk with fatal consequences, for instance. The U.K. HSE determined that both the	

HSE
individual risks and societal concerns endangered by a hazard must addressed, thus suitable controls must be in place to address all significant hazards. In regards to health and safety within the oil and gas industry, HSE has an Energy Division (ED) which is responsible for the offshore oil and gas industry. HSE ED's strategy and priorities for its sector are set out in their Offshore Oil and Gas Sector Strategy 2014 – 2017. The U.K. offshore oil and gas industry consists of 107 oil and gas plus 181 gas producing installations, located on 383 producing fields. There is a supporting infrastructure of 14,000 km of pipelines connecting installations to beach terminals. Industry commissioned many of these assets in the early 1970s and some are now forecast to continue operating to 2030 and beyond. **Oil and Gas Production in the U.K.** The number of mobile offshore drilling units (MODUs) in operation within the U.K. varies year to year, from ten to thirty. Currently, the majority of activity is in the North Sea, with other activity in the Irish Sea and West of Shetland. Some 50 new field developments are planned across all sectors including West of Shetland. West of Shetland, the weather and sea conditions, distances from shore and the absence of a readily available onshore infrastructure present further challenges to the industry. Operators and contractors employ over 32,000 workers in offshore activities. Many tens of thousands more are employed in supporting roles and activities. The strategy aims to secure the safety of all those working offshore. Oil and gas production is strategically important to the UK economy, meeting around 50% of our total primary energy needs. It contributes £50 billion annually to the balance of payments by reducing energy imports and through exported goods. Its U.K. supply chain recorded revenues of £27 billion in 2011. Although declining from the 1999 high, production is expected to continue into the 2050s. £13.5 billion was invested in the sector in 2013 and investment is expected to rise further to exploit new fields and increase recovery in existing fields. 2013 – 2015 will be the most active drilling period in the last 15 years. It is forecast that some 130 wells will be drilled over the next 3 years. **New Regulatory Agency – OSDR (2015)** HSE and the UK's Department of Energy & Climate Change (DECC) , working in partnership, have recently formed the Offshore Safety Directive Regulator (OSDR), to act as the Competent Authority (CA) responsible for implementing the requirements of the European Union's (EU's) Safety of Offshore Oil and Gas Operations Directive of 2013 on the safety of offshore oil and gas operations. The Directive was published following the Deepwater Horizon accident in the Gulf of Mexico. The Directive is also resulting in changes to the U.K. health, safety and environmental regime. OSDR is to be the Competent Authority (CA) responsible for implementing the requirements of the EU Directive on the safety of offshore oil and gas operations. On the 28 June 2013, the EU published the Directive with the aim to reduce, as far as possible, the occurrence of major accidents related to offshore oil and gas operations, and to limit their consequences. The U.K. will need to implement the requirements of the Directive, including the setting up of the CA, by 19 July 2015. The role of the CA, OSDR, is to oversee industry compliance with the Directive and to undertake related functions such as accepting and/or assessing relevant Safety Cases, Well Notifications and other notifications. Reporting of incidents are included as are intervention planning and investigation work. DECC and HSE will work in partnership as OSDR to deliver the CA functions as required under the Directive. Currently DECC's Offshore Oil and Gas Environment and Decommissioning Team (OGED) is responsible for implementing offshore environmental legislation. HSE ED is responsible for implementing health and safety legislation for offshore oil and gas operations. DECC and HSE already work closely together under a Memorandum of Understanding (MOU) for liaison between the two organizations and their regimes. Examples include a coordinated sign-off procedure for all new exploration and appraisal wells, and joint environmental and safety inspections where this is appropriate. The operational MOU is overseen by a high-level cross-Departmental group. However, the existing arrangements need to be expanded to comply with the requirements of the OSDR Directive.

HSE
An enhanced MOU will be established, and will have similarities to the existing model for the regulation of onshore major hazard installations under COMAH. A Senior Oversight Board will govern OSDR, providing organization and direction, and a forum to agree, implement and monitor arrangements and pursue shared strategic regulatory goals. Overall, the U.K. HSE maintains a 'Risk Based' approach whereas the U.S./Japan is more 'Compliance Based' (but moving towards Risk). What this means is U.K. penalizes employers (fines) for not doing duty causing employee personal harm whereas U.S./Japan has focused on compliance of established Regulations and penalizes based on violations of Federal law.
HSE Legal Requirement for a Risk Assessment It is a legal requirement for every employer and self-employed person to make an assessment of the health and safety risks arising out of their work (only needing to record the assessment if the employer has five or more employees). The purpose of the assessment is to identify what needs to be done to control health and safety risks. Regulation 3 of the *Management of Health and Safety at Work Regulations of 1999* states that "Risk" is the chance, high or low, of somebody being harmed by the hazard, and how serious the harm could be. To do a risk assessment, a business needs to understand "Risk" and what might cause harm to people and decide whether they are doing enough to prevent that harm. Once a business has decided that, they next need to identify and prioritize putting in place, appropriate and sensible control measures. This starts with: • Identifying what can harm people in the workplace • Identifying who might be harmed and how • Evaluating the risks and deciding on the appropriate controls, • Recording the Risk Assessment • Reviewing and Updating the Assessment A business's Risk Assessment should include consideration of what in a business might cause harm and how and, the people who might be affected. It does not need to include insignificant risks nor include risks from everyday life unless work activities increase the risk. However, the Risk Assessment should take into account any controls which are already in place and identify what, if any, further controls are required. A business should be able to show from its Risk Assessment that: • A proper check was made • All people who might be affected were considered • All significant risks have been assessed • The precautions are reasonable • The remaining risk is low Risk Assessment's look at both hazards and risk. A "Hazard" is defined as something (i.e. an object, a property of a particular substance, a phenomenon or an activity) that can cause adverse effects. For instance, water on a staircase is a hazard, because you could slip on it, fall and hurt yourself and loud noise is a hazard because it can cause hearing loss. In addition, breathing in asbestos dust is a hazard because it can cause cancer. A "Risk" is the likelihood that a hazard will actually cause its adverse effects, together with a measure of the effect. It is a two-part concept and you have to have both parts to make sense of it. Likelihoods can be expressed as probabilities (i.e. "one in a thousand"), frequencies (i.e. "1000 cases per year") or in a qualitative way (i.e. "negligible", "significant", etc.). **HSE "Reasonably Practicable"/ "As Low As Reasonably Practicable" (ALARP) Policy** The concept of "reasonably practicable" lies at the heart of the British health and safety system, especially as part of HSE's regulatory regime. As previously mentioned, it is a key part of the general duties of the *Health and Safety at Work Act of 1974* and many sets of health and safety regulations that HSE and local authorities enforce. HSE's policy is that any proposed regulatory action (Regulations, Approved Code of Practice (ACOPs), guidance,

HSE
campaigns, etc.) should be based on what is reasonably practicable. In some cases, however, this may not be possible because the regulations implement a European directive or other international measure that adopts a risk control standard different from "reasonably practicable" (i.e. different from what is ALARP). This means balancing the level of risk against the measures needed to control the real risk in terms of money, time or trouble. However, you do not need to take action if it would be grossly disproportionate to the level of risk. Thus, ALARP describes the level to which HSE expects to see workplace risks controlled. Because ALARP is fundamental to the work of HSE, it is important to know its background in U.K. regulatory policy. The definition of ALARP set out by the Court of Appeal (in its judgment in *Edwards v. National Coal Board, [1949] 1 All ER 743*) is: "The term 'Reasonably practicable' is a narrower term than 'physically possible'… a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them." Using "reasonably practicable" allows HSE to set goals for duty holders, rather than being prescriptive. This language flexibility is a great advantage. It allows duty-holders to choose the method that is best for them and so it supports innovation, but it has its drawbacks, too. Deciding whether a risk is ALARP can be challenging because it requires duty-holders and us to exercise judgment as best as possible. **HSE Identified Principal Health and Safety Risks in Offshore Oil Production** HSE's main concern is eliminating the risk of major hazard incidents in which many workers could be killed or injured (i.e. Piper Alpha and Macondo). One of which is *Fire and Explosion*, which can result from the ignition of any released hydrocarbon. Typical sources of hydrocarbon releases (HCRs) are the well, the pipeline riser, other pipelines and pipe work and associated process plant. Releases can occur from either failure of the asset itself due to corrosion, abrasion or fracture, or because of failures of maintenance e.g. poor practice when breaking and re-making joints, or insufficient operational controls. HCRs can also result from damage due to other failures e.g. dropped objects during crane operations. Industry has recognized the importance of controlling HCRs and challenged itself to reduce them. By April 2013, industry had almost achieved its target of reducing releases by 50%. It undertook to achieve a further 50% reduction by 2016. At the end of 2013, HCRs had risen by 30% compared to an equivalent period in 2012. Industry should respond to the challenge it set itself and reverse this unacceptable trend. Floating production installations now account for some 30% of U.K. Continental Shelf (CS) production and their use is likely to increase. In comparison to fixed installations, they have a higher rate of HCRs. Operators of these installations need to act to make sure they eliminate HCRs. Floating installations are also of concern because they can lose stability and buoyancy following collisions, loss of control of ballast systems and environmental action. They can also lose station through failures of anchors and tethers or engine problems. All these risks prevail across the offshore industry. Effective management and control remains central to the continued safety of every offshore installation. Ensuring effective management of these issues will be fundamental to HSE's regulatory activities. Another concern of HSE is *Personal Health and Safety*. Offshore workers are exposed to a range of hazards associated with manual handling, use of chemicals, slips and trips etc. The accident rates offshore are currently about half that of onshore construction and onshore industrial activities and are slightly lower than onshore wholesale/retail activities. HSE is satisfied that the industry overall has demonstrated a good standard of management of these issues. Consequently, it does not plan to proactively inspect personal health and safety conditions, except for noise, hand-arm vibration, mechanical handling/crane operation and on certain installations – asbestos management. However, it will monitor performance to ensure standards are maintained.

HSE
HSE Health and Safety Regulation in Offshore Oil Production Operators of offshore oil and gas installations are subject to a permission regime under the *Offshore Installations (Safety Case) Regulations of 2005*. The primary aim of the Regulations is to reduce the risks from major accident hazards to the health and safety of the workforce employed on offshore installations or in connected activities. These regulations require the operator, before the installation is brought into use, to ensure and then demonstrate to HSE that they have identified all major hazard risks, assessed these risks and applied suitable measures to control the risks. Other regulations, particularly the *Offshore Installations (Prevention of Fire and Explosion, Emergency Response) Regulations of 1995* and *Offshore Installations and Wells (Design and Construction etc.) Regulations of 1996* address key offshore risks and apply to all employers and others responsible for offshore operations. Inspectors undertake their work in line with the HSE's *Hazardous Installations Directorate (HID) Regulatory Model*. They sample key risk control systems to assess the overall management performance of the duty holder. During inspections and investigations, inspectors seek to identify both the immediate reason for the failure and its underlying cause. They also take action both to remedy the immediate problem and secure change that ensures the problem will not recur. Inspectors inform operators and other duty holders of actions necessary to comply with the law. Where inspectors are of the opinion that there is a risk of serious personal injury, they may prohibit the activity. Where they identify significant failures to comply with the law, leading to risk to workers, they require the duty holder to comply within a suitable period. In addition, inspectors may also refer failures to comply with the law to the courts (via the Procurator Fiscal in Scotland, or directly in England and Wales). These matters are referred to the courts to secure either compliance with the law or obtain justice. HSE inspectors exercise their powers in line with the *Regulator's Compliance Code* and the regulatory principles under the *Legislative and Regulatory Reform Act*.
ORGANIZATION APPLICATION OF RISK DATA **HSE Employer Review and Evaluation of Risk Assessment** HSE provides guidance to employers, noting how few workplaces ever stay the same. New equipment, substances and procedures could lead to new hazards that employers need to be mindful of. HSE recommends a regular review of what a business is doing on an ongoing basis, while look at the Risk Assessment again and asking; Have there been any significant changes?; Are there improvements you still need to make?; Have your workers spotted a problem?; Have you learned anything from accidents or near misses?, and; Make sure your risk assessment stays up to date. Having identified the hazards, an employer then has to decide how likely it is that harm will occur; i.e. the level of risk and what to do about it. "Risk" is a part of everyday life and employers are not expected to eliminate all risks. Employers must make sure they know about the main risks and the things needed to manage them responsibly. Generally, HSE requires that employers do everything that is "reasonably practicable." This means balancing the level of risk against the measures needed to control the real risk in terms of money, time or trouble. However, employers do not need to take action if it would be grossly disproportionate to the level of risk. The Risk Assessment should only include what employers could reasonably be expected to know and employers are not expected to anticipate unforeseeable risks. Using information from a Risk Assessment, employers are recommended to do a "self-assessment" and look at what they are already doing and the control measures they already have in place. Employers should ask themselves if they have the capability of ridding the hazard altogether, and if not, how can they control the risks so that harm is unlikely? HSE recommends employers take practical steps including; trying less risky options, preventing access to the hazards, organizing work to reduce exposure to the hazard, issuing protective equipment, providing welfare facilities such as first aid and washing facilities, and involving and consulting with employees. HSE stresses that improving health and safety need not cost a lot to the employer. For instance, placing a mirror on a dangerous, blind corner to help prevent vehicle accidents is a low-cost precaution considering the risks. HSE

HSE

reminds employers that failure to take simple precautions can cost a lot more if an accident does happen. In addition, employers should involve employees so that they can be sure that what employers propose to do will work in practice and won't introduce any new hazards.

If employers control a number of similar workplaces containing similar activities, they can produce a "Model Risk Assessment" reflecting the common hazards and risks associated with these activities. They may also come across "Model Risk Assessments" developed by trade associations, employers' bodies or other organizations concerned with a particular activity. HSE states that employers may decide to apply these "Model Risk Assessments" at each workplace, but they can only do so if they satisfy an employer's requirement that the "Model Risk Assessments" are appropriate for their line of work type of work and that they adapt the "Model Risk Assessment" to the detail of their own work situations, including any extension necessary to cover hazards and risks not referred to in the "Model."

Visual Application of Risk Data

Although HSE does not require businesses to use risk matrices, they can and have been used to help work out the level of risk associated with a particular issue. This is done by categorizing the likelihood of harm and the potential severity of the harm. This is then plotted in a matrix (see below). The risk level determines which risks should be tackled first. According to HSE, using a matrix can be helpful for prioritizing employer's actions to control a risk. It is suitable for many assessments but in particular to more complex situations. However, it does require expertise and experience to judge the likelihood of harm accurately. Getting this wrong could result in applying unnecessary control measures or failing to take important ones.

		Potential severity of harm		
		Slightly Harmful 1	Harmful 2	Extremely Harmful 3
Likelihood of harm occurring	Highly unlikely 1	Trivial 1	Tolerable 2	Moderate 3
	Unlikely 2	Tolerable 2	Moderate 4	Substantial 6
	Likely 3	Moderate 3	Substantial 6	Intolerable 9

Risk Data for HSE Safety Case

Once a Risk Assessment is performed, what operators/ owners and employers must do is prepare a Safety Case, pursuant to the *Offshore Installations (Safety Case) Regulations of 2005*, that demonstrates they have the ability and means to control major accident risks effectively and have it accepted by HSE. HSE requires operators/owners to consult the installation's safety representatives in the preparation, revision or review of the Safety Case. They also must operate the installation in compliance with the arrangements described in the current Safety Case. Also as part of the Safety Case, operators/ owners and employers must implement effective measures to prevent uncontrolled releases of flammable or explosive substances. They must also maintain the integrity of the installation's structure, process plant, temporary refuge and all other equipment as well as the integrity of the wells and the pipelines throughout their lifecycle (this applies to well operators and pipeline operators).

In addition, operator/ owners and employers must prepare a plan for dealing with an emergency should one occur. What employers must do is co-operate with the operator/owner of the installation as well as other employers and other people to ensure the health and safety of those on board the installation and others working in connection with it. In addition, HSE requires that operators/owners and employers are to carry out an assessment of risks that employees are exposed to at work and implement control measures. They are also to provide employees with any health and safety training needed during working time, free of charge. If it is necessary to arrange training outside

HSE
normal hours, this should be treated as an extension of time at work and employers are to provide insurance that covers employees in case they get hurt at work or become ill through work.
References • HSE Risk Assessment Case Studies: http://www.hse.gov.uk/risk/casestudies/ • HSE: Offshore Oil and Gas Sector Strategy 2014 – 2017: http://www.hse.gov.uk/offshore/offshore-strategic-context.pdf • HSE Safety Case Guidelines: http://www.hse.gov.uk/pubns/books/l30.htm • HSE OSDR Website: http://www.hse.gov.uk/osdr/index.htm • HSE Risk Assessment: http://www.hse.gov.uk/pubns/indg163.htm • HSE ALARP Guidance: http://www.hse.gov.uk/risk/expert.htm • HSE Revised Health and Safety Order 2013: http://www.hse.gov.uk/offshore/legislative-changes.pdf • HSE Risk Assessment Templates: http://www.hse.gov.uk/risk/assessment.htm

F.8. NOPSEMA

Table F8 provides detailed information about NOPSEMA.

Table F8. Agency Overview for NOPSEMA

NOPSEMA	
Country of Origin	Australia
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	**CEO,** Stuart Smith **Operations Strategy and Improvement Manager**, Ian MacGillivray Ian.MacGillivray@nopsema.gov.au Telephone: +08 6461 7018 **General Contact** information@nopsema.gov.au Telephone: +61 (0)8 6188 8700
Historical Background/Summary of Mission: The NOPSEMA is Australia's regulatory body for health and safety, well integrity, and environmental management in the offshore oil and gas industry. It was created on January 1, 2012 as a federal response to recommendations arising from the government inquiry following the Montara Disaster in 2009. Martin Ferguson, then Commonwealth Minister for Resources, Energy and Tourism promoted the new agency as a solution to the fragmented regulatory approach to offshore petroleum operations. Prior to NOPSEMA, NOPSA had been the national regulator in charge of offshore petroleum operations. However, NOPSA was only responsible for health and safety issues as described in the Offshore Petroleum and Greenhouse Gas Storage Act 2006. Jurisdiction over well integrity and environmental management was held by other bodies and regulation of coastal waters was still the responsibility of the states and territories. **Consolidation of Jurisdiction** In April 2011, the OPGGSA 2006 was amended to expand NOPSAs function to include regulation of well integrity. In October 2011, the Offshore Petroleum and Greenhouse Gas Storage Amendment Bill 2011 was passed, again extending NOPSAs authority to also include environmental management. Furthermore, the new regulations stipulated that conferral of well integrity and conferral of environmental management authority in coastal waters could no longer occur separately—both powers would have to be conferred simultaneously. The intent was to make it more likely that NOPSEMA would become the national regulator in all three functions and that states and territories would confer all such authority to NOPSEMA as well.	

NOPSEMA

NOPSEMA's geographic jurisdiction includes all Commonwealth waters, excluding coastal waters not conferred to NOPSEMA by the responsible state or territory. To date, only the state of Victoria has conferred responsibility for coastal waters to NOPSEMA. Within this area, NOPSEMA oversees about 30 platforms, 15 FPSO/FSOs, 10 MODUs, 10 Vessels, and 90 pipeline facilities. An additional 60 facilities are located in waters under the jurisdiction of the state of Western Australia which has particularly resisted regulatory consolidation. Upon the transition of NOPSA into NOPSEMA, Western Australia actively withdrew conferral of authority in coastal waters.

Regulatory Powers
NOPSEMA reports to the Commonwealth Minister and members of the COAG Energy Council. In its capacity as a regulator, NOPSEMA is responsible for three categories of action:

- Compliance
- Improvement
- Governance

NOPSEMA monitors activities, inspects facilities, enforces regulations laid out in OPGGSA, and investigates accidents and incidents to meet objectives of compliance. In the area of improvement, NOPSEMA is charged with promoting awareness of health and safety issues and engagement with industry stakeholders on these topics. NOPSEMA also publishes findings, advice, and regulatory interpretation for use by industry. Finally, NOPSEMA is tasked with streamlining governance through strategic reporting to relevant ministers and the NOPSEMA advisory board, cooperation with related functions in offshore regulation, and developing support human resource structure and management methods for efficient performance of legislated tasks.

Regulatory Philosophy
In its mission to ensure human safety, facility structure and well integrity, and environmental management offshores, NOPSEMA has committed to professionalism, ethical behavior, and political independence. In a statement of expectations for NOPSEMA, the Commonwealth Minister for the OPGGS Act laid out goals to maintain regulatory best-practice in order to efficiently and effectively regulate while also minimizing cost and regulatory burden.

As discussed later in this section, NOPSEMA targets a risk-based approach as a means of maximizing efficiency. In this approach, NOPSEMA seeks to invest regulatory and inspection resources toward the processes and systems that are most likely to fail and produce major accidents.

In keeping with policy found in the Australian Government Cost Recovery Policy and the Public Governance, Performance and Accountability Act 2013, NOPSEMA is funded through its own levies and fees placed upon industry. These fees are defined by law and reflect an overarching principle in NOPSEMA's philosophy: the regulator is not responsible for the health and safety of workers or the preservation of the environment—industry is the dutyholder. The operators profit from the collection of publicly owned natural resources and owes it to the public to be safe and clean. As such, they are required to pay for the regulators services to maintain this standard. In the same way, another key component of NOPSEMA's philosophy is its position on oil spill recovery. The agency makes clear that it will not clean up an operator's mess if an oil spill occurs. Instead, NOPSEMA will make sure that before beginning operations, operators have an oil spill recovery plan. The distinction between oversight in oil spill cleanup planning and participation in oil spill recovery is important because it also keeps the responsibility on the operators who are profiting from petroleum production at the will of society.

As part of its efforts to streamline oversight, NOPSEMA also works with other agencies such as the National Offshore Petroleum Titles Administrator which handles operator licensing and other administrative functions and the Australian Maritime Safety Authority which performs a variety of maritime emergency and safety functions. Efforts to streamline regulatory processes with these agencies continue. NOPSEMA also works with similarly-tasked state-level regulators, sometimes being conferred the regulator rights of these agencies, but often simply

NOPSEMA
help in developing best practice regulatory methods and improving government policy. NOPSEMA collaborates on the international level as well. NOPSEMA is an active member of the IRF and hosted the International Regulators Offshore Safety Conference in Perth in 2013. It is also a member of the International Offshore Petroleum Environment Regulators (IOPER), a regulator collaborative group founded to help raise environmental performance standards. **Activities** NOPSEMA works to maintain an attitude of collaboration with all stakeholders in the industry and in the global regulatory sphere. As a tool unto this end, NOPSEMA's website is a dashboard for many of the agencies industry communications. Through it NOPSEMA publishes planning documents such as its annual report and corporate plan. The annual report presents a full range of information compiled from NOPSEMA's and NOPSA's regulatory operations over the last several years. In 2014, the report went back to 2005. The website also contains information that is helpful for industry such as industry performance data, safety alerts, and regulatory guidance and interpretation. NOPSEMA has hosted a number of initiatives, studies and publications. In June 2012, they initiated the Facility Integrity National Program—an initiative intended to reduce the number of hydrocarbon releases through study of reported data on related equipment and piping failures. In a separate initiative, NOPSEMA provided informational resources to operators regarding a number of safety concerns related to lifting operations as identified by the IRF. In addition to these studies, NOPSEMA (or more accurately, NOPSA, prior to 2012) have used surveys to try to reach these parties and bring industry representation into the regulatory process. The Offshore Process Safety Culture survey was used both to collect data about the safety culture observed by the workforce and to raise awareness among workers of the importance of safety culture. The Offshore Process Safety Leadership Principles Survey was similar but directed at leadership and at understanding the companies' safety culture from an organizational structure point of view. The questions were derived from a similar UK document titled Process Safety Leadership Principles and Arrangements. Results were collected and presented to operators in a way so that operators could compare their own organization to their competitors.
ORGANIZATION COLLECTION METHODS OF RISK DATA (RISK INVENTORIES, RISK REGISTERS, TOLERANCE AND ACCEPTANCE LEVELS) According to the Minister of the Commonwealth, essential components of NOPSEMA's risk-based approach are effective industry monitoring, sound information management, and transparent prioritization and operations. Through improved monitoring, NOPSEMA hopes to be able to collect risk-relevant data from operators. By organizing and storing this data systematically, they hope to have risk data available for analysis to support the prioritization of NOPSEMA resources in identification and mitigation of risks. The cornerstone of NOPSEMA's risk based process is their ALARP regime. As stated in the Annual Offshore Performance Report, "By law, offshore petroleum activities cannot commence before NOPSEMA has assessed and accepted the detailed risk management plan documenting and demonstrating how an organization will manage the risks to health and safety to as low as reasonably practicable (ALARP) or the environmental impacts of an offshore petroleum activity to a level that is ALARP and acceptable." In this process, NOPSEMA requires three regulatory documents from the dutyholder: a Safety Case, a well operations management plan, and an environmental plan. The Safety Case is a description of the operator's plans for managing the health and safety of workers at the facilities and evidence supporting the proposition that the operator's plans reduce risk to a level that is ALARP. The Safety Case is focused on high-consequence, low-frequency events and their mitigation. It is assumed that high-consequence, high-frequency events are already sufficiently mitigated through facility design. Low consequence risks are not of major concern. According to NOPSEMA guidance, the Safety Case must essentially answer the following questions (quoted directly): • *What could go wrong?*

NOPSEMA
• *What could cause it to go wrong?* • *What would be the consequences and how likely is it to happen?* • *What is the nature of the risk?* • *What can you do to stop it going wrong?* • *How appropriate are the controls to manage those risks?* • *How can you ensure risks from newly introduced hazards and from changes to existing hazards will continue to be identified and controlled into the future?* • *What do you do if it does go wrong?* • *Will they work properly when you need them to?* • *Does everyone understand their role in stopping it going wrong?* • *Can you take any additional practicable measures to further reduce this risk?* • *Can you demonstrate you are a safe operator?* In answering these questions, acceptable arguments are developed through use of engineering assessment and judgment and risk tools such as QRA. Although NOPSEMA's Safety Case guidance encourage operators to pursue creative solutions, they caveat this with the fact that "industry good/best practice will weigh heavily on what is considered practicable." This caveat may call attention to the regulator's wariness of accepting new methodologies when there is little historical experience to back up the efficacy of the process. Furthermore, NOPSEMA does not deviate from traditional industry objectives such as continuous improvement. It is explained that ALARP does not detract from continuous improvement requirement. Instead, ALARP is the initial process for getting risk levels to a reasonably low baseline. Once this baseline is achieved, continuous improvement is still required. The Well Operations Management Plan (WOMP) contains the operator's hazard register (assessment of anticipated risks) and control measures. In the WOMP the operator must characterize the nature of the well, supplying information about its location, water depth, drilled depth, well activity commencement, period of well activity, individual responsible for well activity, and a listing of materials and equipment to be used on the well. The geological features of the well must also be reported. An assessment of any geological formations, the integrity of the formations, reservoir pressure and other geologic features, reservoir fluids, presence of depleted sands or thieving zones, and the presence of shallow gas zones is required. These issues make up a significant part of the hazard register. Other specific operational risks such as casing corrosion, loss of mud circulation, cross-flow, underground blowout, surface blowout, and hole collapse make up the remainder of the register. In relation to all of the risks identified by the WOMP, the WOMP must address the performance objectives that the operator intends to abide by. These objectives are often accompanied by the systems and strategic management protocols that the operator will put in place to meet the objectives. These strategies detail the individuals, communications, monitoring processes, and emergency response procedures that will be involved in meeting the objectives. Many of the WOMP-related regulations are laid down in part 5 of OPGGS (Resource Management and Administration) 2011 regulations. Section 5.06 addresses New WOMPs. 5.11 addresses changes to WOMPs. 5.12 discusses documentation of changes in understanding of the characteristics of the geology or reservoir that may have a significant impact on a well activity, the occurrence of new detrimental risks or effect to a well activity, and increases in a detrimental risk or effect to well activity. Sections 5.22 and 5.23 define additional specific requirements for NOPSEMA approval prior to carrying out well testing, completion, suspension, abandonment, and intervention activities. The environmental plan discusses the operator's plans for minimizing the environmental impact of petroleum productions in keeping with OPGGS regulations 2009. According to NOPSEMA guidance on the development of environmental plans, the environmental regulations are objective-, risk-, performance-, and system-based. The regulations require industry to submit an environmental plan detailing the controls in place for the safe operation. In determining whether the plan is sufficient, NOPSEMA has laid out specific tests in regulation 10A under part 2 of

NOPSEMA
the OPGGS (Environment) 2009 regulation: • Is the plan appropriate for the scope of the activity? • Does the plan demonstrate that risks will be reduced to ALARP? • Will the environmental impacts and risks be socially acceptable? • Does the plan provide for appropriate performance standards, measurement criteria, and outcomes? • Does the plan lay out its strategy for implementing the necessary monitoring and reporting actions? • Will any production activities take place on a World Heritage Property? • Has the titleholder carried out appropriate consultations and implemented recommendations? • Does the plan comply with relevant regulation? The Safety Case, well operations management plan, and environmental plan are the foundation of NOPSEMA's proactive and preventative regulatory reporting requirements. Besides these documents, accident reporting is also required. Accidents are divided into 3 major categories: Accidents, dangerous occurrences, and environmental incidents. Accidents include deaths, serious injuries, and lost time injuries greater than three days. Dangerous occurrences include hydrocarbon releases, fires, explosions, collisions involving other vessels, potential for an accident, damage to safety equipment, well kicks greater than 50 barrels, pipeline incidents, and other unplanned events. Environmental incidents include hydrocarbon, chemical, and drilling mud releases as well as damage to fauna.
ORGANIZATION APPLICATION OF RISK DATA NOPSEMA's Safety Case, well operations management plan, and environmental plan data are used for establishing the baseline safety measures in the offshore petroleum production environment. Operator's inspections are measured in relation to their reported documentation. Furthermore, many operator actions are not allowed to commence prior to NOPSEMA's approval of their risk documentation. On a broad, industry level, NOPSEMA uses the data to stay informed of current best practice and innovations and to keep industry informed through regulatory action and NOPSEMA publications. Under the OPGGS Act, NOPSEMA is to promote and compliance and share lessons learned with industry through publications such as the Annual Offshore Performance Report. This report is similar to Norway's RNNP in that it surveys a variety of data related to safety, environmental management, and well integrity and displays it as easily understood trend results. The report is a hub for many types of performance indicators including: • Well activity • Facility utilization • Hours worked offshore • Fatalities • Major injuries • Injury cases • Lost time injuries • Accidents • Dangerous occurrences • Reportable incidents • Recordable incidents • Hydrocarbon releases • Environmental incidents • Root cause assessments

NOPSEMA
References • IRF NOPSEMA background: http://www.irfoffshoresafety.com/country/Australia.aspx • About NOPSEMA: http://nopsema.gov.au/about/ • Jurisdiction: http://nopsema.gov.au/about/nopsema-jurisdiction/ • Mission and Values: http://nopsema.gov.au/about/vision-mission-values/ • History: http://nopsema.gov.au/about/history-of-nopsema/ • Leadership Expectations of NOPSEMA: http://nopsema.gov.au/assets/document/Ministerial-Statement-of-Expectations.pdf • Cost Recovery: http://nopsema.gov.au/about/cost-recovery-and-levies/ • International Collaboration: http://nopsema.gov.au/about/international-collaboration/ • Annual Offshore Performance Report: http://nopsema.gov.au/assets/Publications-2/Annual-offshore-performance-report-2013-web.pdf • About Safety Case: http://nopsema.gov.au/safety/safety-case/safety-case-approach/ • Safety Case Guidance: http://nopsema.gov.au/safety/safety-case/safety-case-guidance-notes/ • Well Integrity Guidance: http://nopsema.gov.au/well-integrity/well-integrity-resources/ • Environmental Plan Guidance: http://nopsema.gov.au/environmental-management/environment-plans/

F.9. PSA

Table F9 provides detailed information about PSA.

Table F9. Agency Overview for PSA

PSA	
Country of Origin	Norway
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	**Director General**, Anne Myhrvold anne.myhrvold@ptil.no Telephone: +47 51 87 35 00 **Directors for Supervisory Activities**, Ingvill Hagesaether Foss & Sigve Knudsen ingvill.foss@ptil.no & sigve.knudsen@ptil.no Telephone: +47 51 87 32 41 & +47 51 87 32 69 **Director for professional competence**, Finn Carlsen finn.carlsen@ptil.no Telephone: +47 51 87 32 21 **Director for regulatory development**, Anne Vatten anne.vatten@ptil.no Telephone: +47 51 87 33 43 **Director for operational support**, Jan Arild Asbjornsen jan.arild.asbjornsen@ptil.no Telephone: +47 51 87 35 63 **Head of information**, Inger Anda inger.anda@ptil.no Telephone: +47 51 87 32 01
Historical Background/Summary of Mission: PSA is the Norwegian agency responsible for regulating petroleum industry operations on the Norwegian Continental Shelf. The agency is a spinoff of what had been the Norwegian Petroleum Directorate prior to January	

PSA
1, 2004. Since then, regulatory authority related to HSE has come under PSA. As such, it monitors safety, emergency preparedness, and working environment in the industry. Offshore petroleum exploration, drilling, production, and processing fall under PSA's jurisdiction. The PSA also regulates other related activities such as subsea pipelaying and diving as well as onshore processing plant, pipeline, and power station operations. The PSA does not preside over oil spill clean-up activities, but instead focuses on enforcing preventative efforts against spills. The Norwegian Climate and Pollution Agency and Norwegian Costal Administration handle oil spill clean-up. **Regulatory Powers** In its regulatory role, the PSA issues permits, fines, and prohibitions and conducts audits and verifications in order to enforce the requirements of law for industry. It also has delegated authority to develop and implement new regulation. With all of this authority, the PSA is tasked with maintaining consistent risk-based and system-oriented supervision while also facilitating the flow of relevant information among industry, related regulatory agencies, and other stakeholders. The PSA organization is composed of over 170 staff and is accountable to Norway's Ministry of Labour. The agency works extensively with other agencies including the Norwegian Environment Directorate, the Norwegian Coastal Authority, the Norwegian Industrial Safety and Security Organization, Norwegian Civil Aviation Authority, Norwegian Labour Inspection Authority, Police, and Norwegian Petroleum Directorate. **Regulatory Philosophy** A crucial characteristic of the PSA's philosophy is that industry is responsible for maintaining compliance with regulation at all times, regardless of any inspection activity that the PSA does not carry out. Therefore, the PSA does not approve of industry's plans, but requires industry to submit their plans in order that the PSA has the opportunity to withdraw permission for the implementation of a plan. In this way, the PSA will not be found to have approved any plan or activity which, due to poor construction, leads to injury or disaster. Industry is ultimately responsible for its actions, whether the PSA reviews their plans or not. The PSA makes no attempt to audit every aspect of every petroleum operation in the Norwegian seas. Instead, it works to base regulatory resources on risk, with higher-risk processes and phenomena receiving more attention. They track two broad categories of risk: major accident risk and working environment risk. Working environment risk is high frequency and typically does not have major economic or environmental consequences. Conversely, major accidents are characterized by low frequency, high cost, and large potential environmental impact. This dichotomy of risks presents a resource allocation dilemma to the PSA since it is typically easier to observe working environment risks while it may be more economically and environmentally significant to reduce major accident risk. Prior to the beginning of the PSA, relationships between government, operator, and employee in the petroleum industry were becoming adversarial. Unions claimed that working environment incident rates were increasing while industry reported that the rates were decreasing. The PSA has made it a pillar of their operation that tripartite collaboration between these parties permeates the regulatory process. **Activities** To encourage collaboration and transparency, the PSA hosts forums, conducts industry surveys, and publishes annual reports for circulation among operators, regulators, and employees. The safety forum is a group of individuals representing union, operators, and regulators. The forum meets in an annual conference of about 200 members to discuss current industry priorities related to safety in the offshore petroleum industry. Discussion is often centered on results presented in the RNNP report but also includes

PSA
relevant industry happenings, such as follow-up papers on the Deepwater Horizon disaster. The forum is often research-oriented, facilitating contribution to Health, Safety, & Environmental white papers related to the Petroleum Industry. The Norwegian Oil and Gas Association, Federation of Norwegian Industries, Norwegian Shipowners' Association, Norwegian Union of Energy Workers (SAFE), Lederne, Norwegian Union of Marine Engineers (DSO), Industry Energy (IE), Norwegian Confederation of Trade Unions (LO), and Norwegian United Federation of Trade Unions are all member organizations of the Safety Forum. PSA also hosts the Regulatory Forum. The primary goal of the Regulatory Forum is to achieve consensus on regulatory measures and to maintain a responsive and transparent regulatory environment. Unlike the Safety Forum, the Regulatory Forum does not get heavily involved in discussion of industry research but instead focuses on developing regulation and how to standardize, interpret, and apply the regulatory requirements effectively. The Ministry of Labour (AD), Cooperating Organisations (DSO, the Norwegian Union of Marine Engineers and Norwegian Maritime Officers' Association), Norwegian United Federation of Trade Unions, Norwegian Directorate of Health (Hdir), IndustryEnergy (IE), Norwegian Confederation of Trade Unions (LO), Norwegian Association of Supervisors, Norwegian Shipowners' Association (NR), Federation of Norwegian Industries (NI), Norwegian Oil and Gas Association (Norwegian Oil and Gas), and Norwegian Union of Energy Workers (Safe). PSA also releases a number of journal-style publications every year. “Dialogue” is a journal providing an assessment of current industry events from a regulators perspective. “Safety, Status and Signals” is the regulators annual report in magazine format for easy reading. Perhaps the most important of their publications, however, is the Trends in Risk Level in the Petroleum Activity (RNNP) report, published every spring. This report is a comprehensive, 400-page document laying out (in Norwegian) PSA’s summary of trends in various risk indicator variables over the last several years. More on the RNNP report is found in the Organizational Collection Methods of Risk Data section. A secondary RNNP report related to oil and chemical spills is published every fall. Finally, a 50 page summary document is also published in both Norwegian and English to facilitate international discussion and cooperation related to risk-trending. In the process of assembling the RNNP report, the PSA occasionally performs special studies in order to take a more detailed look at risk drivers. This is especially relevant when the stakeholders want to understand the underlying causal relationships of risk factors. In the last several years, there have been a number of these studies. In 2013, the RNNP report included study titled “Causal relationships and measures associated with structural and maritime incidents”. In 2011, they published the “Causes and measures connected to well control incidents” study. In 2010, they published “Causes and measures connected to hydrocarbon leaks.” Some of these studies are available only in Norwegian.
ORGANIZATION COLLECTION METHODS OF RISK DATA (RISK INVENTORIES, RISK REGISTERS, TOLERANCE AND ACCEPTANCE LEVELS) The RNNP project is PSA’s core risk data project. The project studies risk both on major accident risks—including oil spills, operating accidents, and major accidents—and on working environment risks that workers in the offshore environment must face. The project provides a standard reference for all industry stakeholders for the purposes of measuring regulatory performance, prioritizing regulatory action, prioritizing areas for industry safety improvement, and providing insight into leading indicators of key risks. As stated on the PSA’s RNNP webpage, “RNNP has become an important management tool for all participants in the petroleum sector. Its findings are valuable for our planning of supervision activities and development of the regulations.” The wide applicability of the RNNP results stems in part from the collaboration of a variety of stakeholders in contribution to the report. Besides the PSA, individual operators, the Norwegian Civil Aviation Authority, helicopter operators, an HSE expert group, and Safety Forum contributors all support the process.

PSA

REPORTING REQUIREMENTS

The PSA has issued or is responsible for regulation in multiple distinct spheres including HSE (Health, Safety, and Environment, not the UK's Health & Safety Executive) Framework, Management, Facilities, Activities, Technical and Operational Regulations, Working Environment, and other regulations. For most of these spheres, data collection requirements for the industry are specified.

The HSE Framework regulations set the standards for preserving health, safety, and the environment in the offshore petroleum industry. The regulations specifically address reporting in sections 25, 26, and 28. The sections cover the compliance for mobile facilities, entry into safety zones, and documentation of the early phases of production.

Management Regulations requires that any data significant to HSE functions are collected for the purpose of supporting activities related to monitoring processes, preparing parameters, supporting and following up on analysis, assembling datasets, and implementing remedial and preventive measures. These requirements are covered in section 19 of the Management Regulations. Sections 25, 27, 33, and 35 through 39 of the management Regulations indicate specific reports required to be filed related to deaths, injuries, drilling, diving, well activities, accidents, structural damage, working hours, work-related illness, and labor disputes.

The Facilities regulations require instrumentation for collection of new data related to corrosion in and environmental conditions in newly explored areas of the PSA's jurisdiction.

Activities regulation Industry is required to collect data about their continuous improvement of facilities' and parts' performance and their technical monitoring of structure, maritime, and pipeline system conditions. Documentation of technical monitoring and comparison to design calculations is specifically required for structures in their first year of operations and for the first two winter seasons of new structure types. Other sections specifically require documentation of environmental impact and plans for the installation, development, and operation of a facility. All of these requirements are covered in sections 4, 20, 49, 50, and 84 of the Activities Regulations.

The Technical and Operations Regulations require industry to collect data on strain and injury risk based on employee's experiences and also to provide this and similar information to their employees so that employees can be familiar with the risks and injuries identified by prior employees. Any data that could indicate possible well control incidents are also monitored, recorded, and processed. These requirements are covered in sections 46 and 53 of the Technical and Operational Regulations.

The input data for the RNNP are described in Table 7 in Section 3.2. As described in that section, the RNNP project uses data from a variety of sources, including required industry reporting of incidents; voluntary reporting of additional data related to occurrences of near misses, fires, evacuations, dropped objects, etc.; and data from a biannual questionnaire along with data collected through PSA interviews and fieldwork. Although responses are not legally required for the questionnaire or voluntary data submissions, there is a sort of gentlemanly agreement between the unions, regulators, and industry to work together in collecting this data in the interest of smoothing out differences in opinion between unions and industry regarding the industries risk level.

ORGANIZATION APPLICATION OF RISK DATA

The RNNP is probably the PSA's biggest direct application of risk data. A lot of reported data are simply for assessing an operator's ability to meet regulatory standards for operation. However, the aggregation of the data in the RNNP turns simple reporting data into risk data.

Each key variable collected for the RNNP project is referred to as a Defined Hazard and Accident Condition (DFU). The RNNP report analyzes trends in a variety of DFUs, listed below:

- Non-ignited hydrocarbon leak
- Ignited hydrocarbon leak

PSA
• Well incident/loss of well control • Fire/explosion in other areas, combustible liquid • Ship on collision course • Drifting object • Collision with field-related vessel/facility/shuttle tanker • Damage to platform structure/stability/anchoring/positioning fault • Leak from subsea production facility/pipeline/riser/wellstream pipeline/loading buoy/loading hose • Damage to subsea production equipment/pipeline systems/diving equipment caused by fishing gear • Evacuation (precautionary/emergency evacuation) • Helicopter crash/emergency landing on/near facility • Man over board • Personal injury • Work-related illness • Full loss of power • Diving accident • H2S emission • Falling object Some of these DFU's are collected through required incident data reporting and voluntary reporting by industry. These do not include the data collected through the PSA's biannual worker questionnaire. While the DFU's focus primarily on major accident risk and the questionnaire is geared more toward working environment risks, some level of overlap allows for comparison and checking of the observed trends against each other, as described above. The overarching principle in the RNNP project is that risk levels should not be allowed to rise. It is a philosophy that is understood and agreed upon by the regulator, industry, and other stakeholders. As such, the report sets the tone for all stakeholders and affects legislation and inspection priorities as well as industry expectations and operations. It is a philosophy on continuous improvement through cooperation between the regulator and industry rather than a stiffly enforced and somewhat theoretical ALARP or Safety Case procedure. The project has also facilitated more in-depth studies. For example: early in the existence of the RNNP project, the PSA discovered good trends in a number of risk factor at a number of facilities. In response, the PSA performed a special study, seeking to identify what sorts of changes had led to these positive improvements at these facilities. The result of this study could then be incorporated into the PSA's regulatory strategy so that all of Norway's offshore facilities could achieve similar gains in safety. Similarly, any risk factors that are perceived to be increasing are directly addressed through allocation of inspection and regulatory resources.
References • PSA Leadership: http://www.psa.no/senior-management-team/category982.html • PSA Background: http://www.irfoffshoresafety.com/country/Norway.aspx • PSA Background: http://www.psa.no/how-we-work/category991.html • PSA Jurisdiction: http://www.psa.no/role-and-area-of-responsibility/category916.html • PSA Regulations: http://www.psa.no/regulations/category216.html • Safety Forum Information: http://www.psa.no/safety-forum/category917.html • Regulatory Forum Information: http://www.psa.no/regulations/regulatory-forum-article9524-216.html • RNNP Background: http://www.psa.no/about-rnnp/category911.html • Contributors to the RNNP: http://www.psa.no/contributors-to-the-rnnp/category979.html • RNNP Studies: http://www.psa.no/rnnp-and-major-accident-risk/category977.html • RNNP Studies: http://www.psa.no/studies-conducted-for-the-rnnp/category1167.html

Table F4 provides detailed information about CNH.

F.10. SSM

Table F10 provides detailed information about SSM.

Table F10. Agency Overview for SSM

SSM	
Country of Origin	Netherlands
Public or Private Sector	Public
Government/Organization Points of Contact (POCs)	**Inspector General of Mining**, J.W. de Jong j.w.dejong@minez.nl Telephone: (070) 379 84 31

HISTORICAL BACKGROUND/SUMMARY OF MISSION:

As the name implies, the Netherlands' SSM has its heritage in mineral mining. Coal mining in the Netherlands began in the 14th century and the SSM began with the passing of the Mining Act by Napoleon in 1810. The act has since been revised and updated, but SSM continues to this day as the national regulator over the detection and extraction of minerals.

The agency has historically presided over the mining of coal, salt, and minerals onshore in the Netherlands. With the discovery of the Groningen natural gas field in the 1960s, the Netherlands become one of the world's leading natural gas producers. It is estimated that the Groningen field still contains a trillion cubic meters of natural gas. About half of the Netherlands nearly 80 billion cubic meters of natural gas production still come from this reservoir, with the remaining half coming from other smaller reservoirs.

Today, SSM is responsible, not only for the harvesting of natural resources, including petroleum and natural gas, but also for the disposal of carbon dioxide and greenhouse gases underground in retired mines and caverns, temporary storage of natural gas underground, harvesting of geothermal energy from water heated by the earth's heat in deep mines, and the use of wind farms offshore for generating power.

Recently, a number of incidents lead to the Dutch Safety Board examination of seven incidents. The board determined that additional regulatory pressure in the area of health and safety of workers was necessary. Because of its existing regulatory authority over mining and drilling activity, SSM received responsibility for health and safety functions. Although SSM has only about 60 employees, they claim one of the world's safest mineral extraction industries.

SSM is led by the SSM Inspector General and is an agency of the Ministry of Economic Affairs, Agriculture and Innovation. It derives its regulatory authority from a substantial list of legislation including the Mining Act, Working Conditions Act, Environmental Management Act, Working Hours Act, Nuclear Energy Act, Chemical Substances Act, Commodities Act, Soil Protection Act, Noise Abatement Act, Air Pollution Act, Surface Waters Act, Marine Pollution Act, Water Supply Act, and the Gas Act (article 8, safety).

Regulatory Activities

SSM performs regulatory tasks in two main categories: compliance and policy development. SSM's compliance activities include enforcing the wide variety of legislation that SSM is responsible for as it relates to detection, extraction, and transportation of minerals. SSM's role in policy development includes its role in informing decisions of the Minister of Economic Affairs and its function in providing independent comments and evaluation of proposed or existing policy as well as keeping policy directors informed of policy developments abroad.

SSM also provides supporting functions to the Minister of Social Affairs and Employment, the Minister of Housing, Spatial Planning and the Environment, and the Minister of Health, Welfare and Support regarding working conditions and labor law issues, environmental issues, and criminal investigations respectively. The agency works under the Public Prosecutor which is responsible for special government investigative powers.

In performing these tasks, SSM teams are divided between Operations, Engineering, and Geo-engineering. An

SSM
additional business area performs administrative support for these three other areas. SSM regulates about 150 fixed offshore oil and gas installations, 10 MODUs, 2500 km of offshore high pressure pipelines, and 2 Offshore wind farms. About 20 companies operate offshore in SSM's jurisdiction. **Regulatory Philosophy** SSM's vision is guided by the Netherlands commitment to becoming one of the cleanest and most economical countries in the world. 'Clean and Efficient: New energy for the climate' is a government program that outlines the Netherlands environmental targets, which include a 30% reduction in greenhouse gases and a 10-fold increase in the percentage of energy production through sustainable energy by 2020. These objectives and SSM's responsibility for work health and safety drive the agency's vision as expressed on its website: • To limit the number of accidents and the level of pollution as much as possible • To use existing infrastructure for onshore mineral exploitation and geothermal as much as possible • To maximize use of possible underground carbon dioxide storage • To solicit cooperation of operators On its path to achieving its missing, SSM has laid out six attributes to target in its supervisory approach: selective, proactive, collaborative, independent, transparent, and professional. In these attributes, SSM sees the ability to efficiently and effectively oversee industry, initiating intervention before disaster occurs and reflecting public concerns and desires while avoiding political entanglements. Finally, SSM uses a three-pronged methodology in oversight. First, new activities performed by industry are examined and screened prior to in a proactive oversight step prior to the operations beginning. Second, existing operations are required to document activities, are to submit to SSM inspections, audits, and other preventative measures. Third, SSM maintains the power to perform investigations, inflict penalties, and carry out other response measures in reaction to industry accidents and non-compliance. **Activities** SSM publishes various reports and papers covering industry happenings and regulatory strategies. The agency produces a monthly health and safety bulletin discussing current issues and developments. Additionally, since 2007, SSM has published the Strategy and Programme report. This 120 page report outlines the agency's objectives relating to health and safety, the environment, subsidence, optimal mineral resource use, technical integrity of gas transport and distribution networks, and the its measurement, analysis, and improvement initiatives. The report sets timetables for its goals over the next 5 years and comments on its success in fulfilling the goals stated in the prior planning period. The report appendices include a wide variety of statistics and metrics, detailing gas and petroleum production levels, facts about the agency, SSM's expenditures as compared to other similar agencies in Europe, etc.. SSM's risk management initiatives are also discussed in this document. As is typical of industry regulators, SSM works to maintain a relationship with the unions that are impacted by its jurisdiction. FNV Bondgenoten is the primary union that SSM contacts, but Unie, Nautilus, and CNV are involved in SSM's activities. Involvement with the unions allows SSM to satisfy two objectives. Trade unions expect to be advised regularly about developments in health and safety and to be able to weigh in on policy related issues. SSM is the means for this necessary communication for maintaining connection between government and worker in health and safety concerns in the offshore environment. SSM cooperates with operators through organizations like HSElife Unio (Unio), a forum sponsored by SSM and a group of operator organizations including Casos, IRO, and NOGEPA. Many of the Netherland's operating companies are members of Unio. The forum exists to develop standardized internal controls for HSE in the Netherlands offshore operations. Since many workers on offshore platforms are contractors, a standardized set of HSE protocols improves understanding of expectations. The organization facilitates HSE discussion and maintains a commitment to pursuing a zero-incident offshore workplace.

SSM
SSM maintains international cooperation as well. It is a member of the IRF. It participates in the North Sea Offshore Authorities Forum along with the UK, Ireland, Norway, Denmark, Germany, Sweden and the Faroe Islands. SSM also offers consultation to the OSPAR Commission to protect the environment in the North-Eastern Atlantic and maintains relationships with multiple individual agencies in other European countries. It works with the German Mining Authority in the North Rhine-Westphalia, the French DRIRE (salt extraction) and the British CEFAS (environment and fishing).
ORGANIZATION COLLECTION METHODS OF RISK DATA (RISK INVENTORIES, RISK REGISTERS, TOLERANCE AND ACCEPTANCE LEVELS) SSM's Strategy and Programme 2012-2016 publication identifies the following risks areas associated with oil and natural gas production. • Internal: accidents such as explosions, collisions, and helicopter crashes lead to injuries and fatalities of workers in the industry • External: leaks of natural gas and explosions can cause injuries and fatalities among nearby residents. • Environmental: blowouts and leaks can contaminate marine, soil, and atmosphere environments. • Geophysical: large productions can lead to ground subsidence and earthquakes. • Mineral/Economic: poor mining/drilling practices can decrease operator's ability to exploit resources Many of these risks are controlled through regulation of industry practices. The health and safety risks are mitigated in part by putting more onus on industry. SSM requires that operators submit a health and safety document every 5 years. Although this document is similar to a Safety Case, as performed in the UK, there is no ALARP requirement attached to the document.
ORGANIZATION APPLICATION OF RISK DATA SSM's vision regarding risk analysis is reflected well in the following quotation, taken from their 2012-2016 "Strategy and Programme" publication: *"Supervision also allows government to reflect their policies. Furthermore, it provides insight into the level of enforcement in a sector and the effectiveness of the regulations. While it may not always be pleasant for a department or Minister, it does offer the security that a Minister can take his responsibility timely. State Supervision of Mines (SSM) fulfils its role in a complex, highly technical and international environment. Within the limitations of the people and resources available to the departments, SSM must constantly assess where to deploy its people and resources and where it needs to intervene. Risk analysis forms an important part of this."* Since the Macondo accident, SSM has increased focus on barriers to accidents. They have worked to encourage industry to develop increased expertise in the application of barrier modeling such as bow-tie methodology. Additionally SSM has requested that industry develop barrier performance metrics and management systems for improving these metrics. Operators have their own methods of improving HSE performance. They track leading indicators and performance indicators such as: • Maintenance backlog of mechanical safety components • Ratio of number of actual safety studies carried out to the number planned. • Ratio of number of inspections from management to the number of inspections planned. • Number of outstanding action items following inspections • Reported near-misses • Percentage of safety-critical components not in order • Number of active alarms Given the proactive safety culture in the Netherlands petroleum operations, it appears that SSM is able to provide sufficient oversight with relatively minimal regulatory intervention.

SSM
REFERENCES • SSM in the IRF: http://www.irfoffshoresafety.com/country/Netherlands.aspx • About SSM: http://www.sodm.nl/english/organisation • Mission, Vision, and Strategy: http://www.sodm.nl/english/organisation/mission-vision-and-strategy • Organizational Structure: http://www.sodm.nl/english/organisation/organisational-chart • What SSM does: http://www.sodm.nl/english/organisation/what-does-ssm-do • Org Chart: http://www.sodm.nl/sites/default/files/redactie/organogram%20sodm%20juli%202014.pdf • CO2 Storage: http://www.sodm.nl/english/subjects/co2-storage • Geothermal Energy: http://www.sodm.nl/english/subjects/geothermal-energy • Oil and Gas Operations: http://www.sodm.nl/english/subjects/oil-and-gas-extraction • SSM Strategy & Programme 2012-2016: http://www.sodm.nl/sites/default/files/redactie/sodm_strategy_2012-2016.pdf • HSE Bulletins: http://www.sodm.nl/english/publications/hs-bulletins • Safety Documents: http://www.sodm.nl/sites/default/files/redactie/04-14%20vg-documenten%20addendum%20gebruik%20eng.pdf

G. Glossary of Terms

Term	Definition
Adaptive resolution	Efficient risk analysis approach where methods build from simple to moderate to complex by screening out issues that do not warrant further analysis as a function of the issue's assessed risk and uncertainty.
ALARP	Principle applied by many health and safety regulators to ensure that the residual risk of operations they regulate are as low as reasonably practicable, which is different from as low as possible. The goal of this approach is to ensure operations are within societal risk tolerances, and that there is a rational balance between the costs of risk reduction and the value achieved in reducing the risk.
Anomalous Condition Risk Importance (ACRI)	In NASA risk management, a qualitatively-defined measure of the risk importance of the occurrence with respect to the benchmark system risk.
Bowtie Analysis	Similar to LOPA, bowtie analysis is a technique for identifying layers of protection for major accident hazards, but bowtie enables analysts to consider multiple scenarios simultaneously. Bowtie is a particularly effective technique for communicating the relationships between prevention/mitigation layers and the scenarios that address.
Change Analysis	Change analysis looks logically for possible risk effects and proper risk management strategies in changing situations (e.g., when system layouts are changed, when operating practices or policies change, when new or different activities will be performed).
Common Cause Failure	Multiple failures of functions, systems, or equipment as a result of a single phenomenon
Conditional Consequence Index (CCI)	In NASA risk management, the likelihood of a severe consequence, given that the component has failed.
Core damage frequency (CDF)	In NRC risk management, core damage frequency (CDF) is the sum of the frequencies of those accidents that result in the reactor core being uncovered to the point at which significant damage to the core is anticipated.
Data accuracy	Data accuracy is the degree to which the data reflects reality
Data precision	Data precision is the level of detail expressed in the data. For numerical data, precision might mean the number of digits shown after the decimal point.
Data relevance	Data relevance describes how closely data fits the purpose for which it is used.
Data variety	Data Variety is the problem of data being inconsistently formatted or unstructured. For example, requiring operators to provide spreadsheet summaries of their operations may yield a lot of informative data. However, if each organization arranges its summary in a different format, it may be difficult to make these data useful. This is variety due to inconsistent formatting. Unstructured data, such as free text data, also presents variety issues.
Data velocity	Data Velocity of data occurs when new data are continually becoming available and, therefore must be processed continually to be relevant.
Data volume	Data Volume is the problem of having a large number of records and/or fields in a dataset. The higher the data volume, the harder it can be to comprehend features of the data and the longer it may take for computers to process the data
Event Tree Analysis (ETA)	ETA is an analysis technique that uses decision trees to model the possible outcomes of an event that can produce an accident of interest. Probabilities and frequencies can be added to the analysis to estimate risks numerically.

Term	Definition
Failure Condition Index (FCI)	In NASA risk management, the likelihood of component failure of concern given occurrence of anomalous condition acting on the component.
Failure Modes and Effects Analysis (FMEA)	FMEA is a reasoning approach best suited to reviews of mechanical and electrical hardware systems. The FMEA technique (1) considers how the failure modes of each system component can result in system performance problems and (2) makes sure the proper safeguards are in place. A quantitative version of FMEA is known as failure modes, effects, and criticality analysis (FMECA).
Fault Tree Analysis (FTA)	FTA is a technique that graphically models how logical relationships between equipment failures, human errors, and external events can combine to cause specific accidents of interest. Probabilities and frequencies can be added to the analysis to estimate risks numerically.
Fussell-Vesely Importance	In NRC risk management, Fussell-Vesely Importance of a SSC is defined as the fractional decrease in total risk level when the SSC is assumed perfectly reliable
Grossly disproportionate	The goal of the ALARP approach is to ensure operations are within societal risk tolerances, and that there is a rational balance between the costs of risk reduction and the value achieved in reducing the risk. If the costs are grossly disproportionate (e.g., cost/benefit ratio, which is also known as the Proportionality Factor [PF] > 10), then the further improvement is not required and the risk has been reduced to ALARP (assuming that the risk is lower than the tolerability threshold).
Hazard and Operability (HAZOP) Analysis	The HAZOP analysis technique uses special guide words for (1) suggesting departures from design intents for sections of systems and (2) making sure that the proper safeguards are in place to help prevent system performance problems.
Large early release frequency (LERF)	In NRC risk management, large early release frequency (LERF) is the frequency of those accidents leading to significant, unmitigated releases from containment in a time frame prior to effective evacuation of the close-in population such that there is the potential for early health effects.
Layer of Protection (LOPA) Analysis	LOPA is a technique to systematically identify and assess the number and strength of layers of protection against major accident hazards. This information is used to make consistent and rational decisions on the adequacy of existing or proposed layers of protection.
Monte Carlo	Monte Carlo methods are used to compute the risks within PRA models. This technique allows analysts to consider variations in each factor of the analysis, imperfect knowledge, as well as the many possible ways the factors can interact.
Pairwise Comparison	Pairwise comparison is a risk ranking technique for multiple issues that relies on a collection of SMEs systematically rating the relative risks between combinations of two issues. This relative ranking is repeated for every possible combination, and the group results are combined mathematically to generate summary rankings.
Pareto Analysis	Pareto analysis is a ranking technique based only on past data that identifies the most important items among many. This technique uses the 80-20 rule, which states that about 80 percent of the problems are produced by about 20 percent of the causes.
Performance-Based Regulation	A regulatory approach that focuses on desired outcomes, rather than prescriptive processes, techniques, or procedures.

Term	Definition
Preliminary Risk Analysis (PrRA)	PrRA is a simplified approach to accident-based risk assessment. The main goal of the technique is to define the risk related to important accident scenarios. This team-based approach relies on SMEs examining the issues. The team suggests possible accidents, most important contributors to accidents, and protective features. The analysis also identifies the risk of the accidents and identifies recommendations for reducing risk.
Prescriptive Regulation	A regulatory approach that defines how processes, techniques, and procedures are to be undertaken.
Probabilistic Risk Assessment	Probabilistic risk assessment (PRA) systematically looks at how the pieces of a complex system work together to ensure safety. PRA allows analysts to quantify risk and identify what could have the most impact on safety.
Relative Ranking/Risk Indexing	Relative ranking/risk indexing uses measurable features of an operation or facility to calculate index numbers that are useful for comparing risks of different options. These index numbers can, in some cases, be related to actual performance estimates.
Risk Achievement Worth (RAW)	In NRC risk management, Risk Achievement Worth (RAW) of a SSC is the increase in risk if the SSC is assumed to be failed at all times. It is expressed in terms of the ratio of the risk with the SSC failed to the baseline risk level.
Risk Management Cycle	The recommended risk management cycle is made up of five phases as shown in Figure 1: (1) setting strategic goals, objectives, and determining constraints; (2) assessing the risks; (3) evaluating alternatives for addressing these risks; (4) selecting the appropriate alternatives; and (5) implementing the alternatives and monitoring the progress made and the results achieved. This cycle was introduced by GAO in 2005. The GAO risk management cycle, while generic, provides a useful framework for weighing the value of alternate risk mitigation strategies.
Risk Reduction Worth (RRW)	In NRC risk management, Risk Reduction Worth (RRW) of a SSC is the decrease in risk if the SSC is assumed to be perfectly reliable. It is expressed in terms of the ratio of the baseline risk level to the risk with the SSC guaranteed to succeed.
Safety Case	A Safety Case is a structured argument by a dutyholder to demonstrate that their facility will ensure health, safety, and wellfare within societal risk tolerances in order to achieve government approval to operate.
So Far As Is Reasonably Practical	see ALARP
Trend Analysis	Trend analysis is a technique to analyze historical accident and near miss data over time to identify consistent trends to predict future accidents. This technique is best suited to high frequency/low severity profiles.
What-if Analysis	What-if analysis is a problem-solving approach that uses loosely structured questioning to (1) suggest upsets that may result in accidents or system performance problems and (2) make sure the proper safeguards against those problems are in place.