Submission to

The Senate Standing Committees on Environment and Communications

Inquiry into Oil or Gas Production in the Great Australian Bight

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Introduction

This submission relates to the Senate Committee's term of reference (a), and other related matters.

On October 11, 2016, BP announced that: "*BP has taken the decision not to progress its exploration drilling programme in the Great Australian Bight (GAB), offshore South Australia*" (BP Press Release, 11 October 2016). Because of the importance of future exploratory drilling in the Great Australian Bight, this document has been completed and submitted to the Senate Committee.

A fundamental requirement for the proposed BP exploratory drilling in the Great Australian Bight (GAB) is that a Safety Case Regime be properly implemented and maintained before and during conduct of the proposed and future developments (NOSEMA, 2013). The Safety Case Regime requires the Major Accident Event (MAE) Risks (Likelihoods and Consequences of Major Accident) must be As Low As Reasonably Practicable (ALARP) (NOPSEMA, 2013, 2012).

This document summarizes results from a Quantitative Risk Assessment (QRA) of the MAE associated with an Uncontrolled Blowout during conduct of the proposed BP GAB exploratory drilling projects – Stromlo-1 and Whinham-1 (BP Australia, 2016c). A QRA was used for the reasons proposed by NOPSEMA (2012): "*Better suited to more complex decision making or where risks are relatively high" and "More rigorous, detailed and objective than other methods and can better assist choice between different control options*."

The BP GAB exploratory drilling 'Systems'[2] Uncontrolled Blowout MAE QRA are developed for two conditions: 1) as presently proposed by BP, and 2) revised with specified additional MAE Risk mitigation provisions.

Background for the QRAs have been based on documentation currently publically available on the proposed BP GAB exploratory drilling developments provided by: 1) this Senate Inquiry, 2)

[2] 'Systems' include the combination of: 1) Operators, 2) Organizations, 3) Hardware, 4) Procedures, 5) Structures, 6) Environments, and 7) Interfaces between these components. These components are inter-connected, inter-dependent, and highly inter-active.

NOPSEMA, and BP.

Due to BP and legislated NOPSEMA requirements to maintain Private & Confidential Information, many of the important 'details' concerning performance of the proposed exploratory drilling systems currently are not available to the public. Documentation submitted to this Senate Committee have been used together with information available from comparable previous exploratory drilling Systems and operations in other offshore areas (e.g. U.K. and Norwegian Sectors of North Sea, U.S. Arctic, Canadian East Coast, Greenland) (Khorsandi, 2011) have been used to 'fill in the gaps' of information currently available to the public.

Results from the QRA based on the proposed BP GAB exploratory drilling Systems indicate the Risk of an Uncontrolled Blowout during exploratory drilling is not ALARP. Both the assessed Likelihood and Consequences exceed historic performance, economics cost-benefit, and standards-of-practice guidelines for determination of ALARP Risks associated with MAEs (Bea 1990, 1991, 2000, 2016; Hartford, 2009). This assessment has not included the regulatory requirements that NOPSEMA must meet in relation to environmental protection – being that impacts and risks to matters of national environmental significance are 'Acceptable' (NOPSEMA, 2014a, 2014b).

Results from the QRA with specified additional MAE Mitigation provisions to the currently proposed BP GAB exploratory drilling Systems indicate the Risk of an Uncontrolled Blowout could be developed to be ALARP if the following provisions are properly developed and implemented:

1) Reduce the Likelihood: Systems Operators and Organizations adopt and maintain additional procedures and processes that will develop Higher Reliability Organizations having Higher Reliability Management and Systems (Bea, 2011), and

Reduce the Consequences: Provisions for emergency controls and mitigations of an uncontrolled blowout during exploratory drilling include mobilization a relief well drilling System that would be staged at a nearby location such that it could arrive on site and be capable of drilling a relief well under anticipated GAB conditions within specified timeframes. Relief wells have proven to be the ultimate well blowout source control (Pew Charitable Trusts, 2013). The relief well activity would be conducted in parallel with the other source control response techniques proposed by BP (closure of BOP, ROV mobilization to close BOP, Capping Stack deployment) (BP 2016b). An alternative to the nearby relief well System would be to have an on-site (nearby) relief well System whose simultaneous drilling progress ‘lags behind’ the primary drilling system enabling use of experience and information developed by the primary drilling System allowing reliable rapid closure of the blowout well. The ‘Same Season’ relief well option was formally required by the U.S. Department of Interior (2015) for exploratory drilling on the U.S. Arctic Outer Continental Shelf. The ‘Same Season’ relief well option was used during 2015 by Shell in exploratory drilling of the Burger Prospect in the Chukchi Sea, Alaska (Shell, 2013).

To assist NOPSEMA and this Senate Committee determination that the Systems utilized in the BP GAB exploratory drilling program and future GAB exploratory drilling programs can and will develop ALARP Risk associated with an uncontrolled blowout, it is recommended NOPSEMA develop and appoint an Expert ALARP Risk Panel comprised of experienced, qualified individuals representing four concerned constituencies: 1) the Australian governments, 2) the Australian public, 3) the Australian and International oil and gas industry organizations, and 4) the organizations representing maintenance of environmental quality. This Expert ALARP Risk Panel would be charged with development of a summary report submitted to this Senate Committee and NOPSEMA. The industry representatives should include experts with extensive experience in drilling engineering and operations, blowout source control, and Risk Assessment & Management.

If the Senate Committee would like to discuss these findings and recommendation, the author would be privileged to appear before the inquiry via telephone or video conference.

ALARP Risks

A fundamental goal of NOPSEMA’s Safety Case Regime provisions, and other similar provisions developed and implemented in the U.K. by the Health and Safety Executive (Health and Safety Executive, 2005) is development and maintenance of offshore drilling and production systems that can and will have ALARP MAE Risks. The MAE Risks are characterized with two primary factors: 1) the Likelihoods (e.g. probabilities) of major failures, accidents, and disasters (MAEs), and 2) the Consequences of MAEs.

Assessments of the Likelihoods of MAEs should include consideration and assessments of the effects of four basic types of Uncertainties: Type 1) Natural Variabilities; Type 2) Analytical Model Uncertainties; Type 3) Human and Organizational Decision Making and Task Performance Uncertainties, and Type 4) Human and Organizational Information Acquisition, Analysis, and Utilization Uncertainties (Bea 2000, 2002).

Extensive experience with RAM has demonstrated Type 4 Uncertainties are of particular importance in development of MAE QRAs. Type 4 Uncertainties can be organized into two categories: 1) Unknown Knowables – sometimes referred to as "Black Swans;" and 2) Unknown Unknowables – sometimes referred to as "Unpredictable Crises" (Bea, 2008).

Uncertainties associated with Unknown Knowables can be addressed by development of Systems whose Organizations and Operating Groups are constantly alert for knowledge and information about risks that have not been previously recognized and have aggressive processes and procedures for the acquisition and proper utilization of such knowledge.

Uncertainties associated with Unknown Unknowables can not be predicted in advance of the decision and implementation processes associated with System operations. Recognition, assessment, and management of these uncertainties is frequently described as 'Crisis Management' or 'Emergency Management.' Successful recognition, assessment, and management of these uncertainties involves continual efforts by the involved Organizations and Operating Groups to "Observe, Orient, Decide, and Act" – known as "OODA Looping." This is 'Real-Time' ALARP System 'Interactive' (performed during conduct of operations) Risk Assessment and Management (RAM) (Bea, 1998, 2008).

Interactive RAM is one of three essential Components in Systems developments and operations (Bea, 1999a, 199b, 2000). Proactive RAM is developed before System operations are conducted; the focus is on Prevention of Major Accidents. Reactive RAM is developed after operations are conducted; the focus is on 'Learning' and 'Mitigation of Consequences.'

Three fundamental Approaches are applied in development of these three RAM Components: 1) reduce the Likelihoods of MAEs, 2) reduce the Consequences of MAEs, and 3) Increase the Detection and Mitigation of System 'malfunctions' to prevent and control MAEs. If ALARP

MAR Risks are to be realized, ALL three of these Components and Approaches must be effectively developed, implemented, maintained, and revised throughout the life-cycle (concept development, design, construction, operation, maintenance, decommissioning) of Systems (NOPSEMA, 2013, 2015).

Analytical results from System MAE QRAs can be expressed as summarized in Figure 1 – identified as the 'Risk Space.' The vertical axis is the Likelihood of a particular type of System MAE. This Likelihood generally is expressed in terms of Probabilities having a specified 'time frame' – e.g. per year or other time measure of the System operation/s. The horizontal axis in Figure 1 is a measure of potential Consequences associated with a specified MAE. In Figure 1, the Consequences are expressed in monetary 'Cost' terms (U.S. 2010 Dollars, $) that include direct, indirect, on-site, off-site, immediate, long-term, property, productivity, commercial – industrial, public – social, and environmental impacts. Other quantities can be used to express Consequences that are of importance in the decision-making processes involved in determination and definition of MAE ALARP Risks (Bea, 2000).

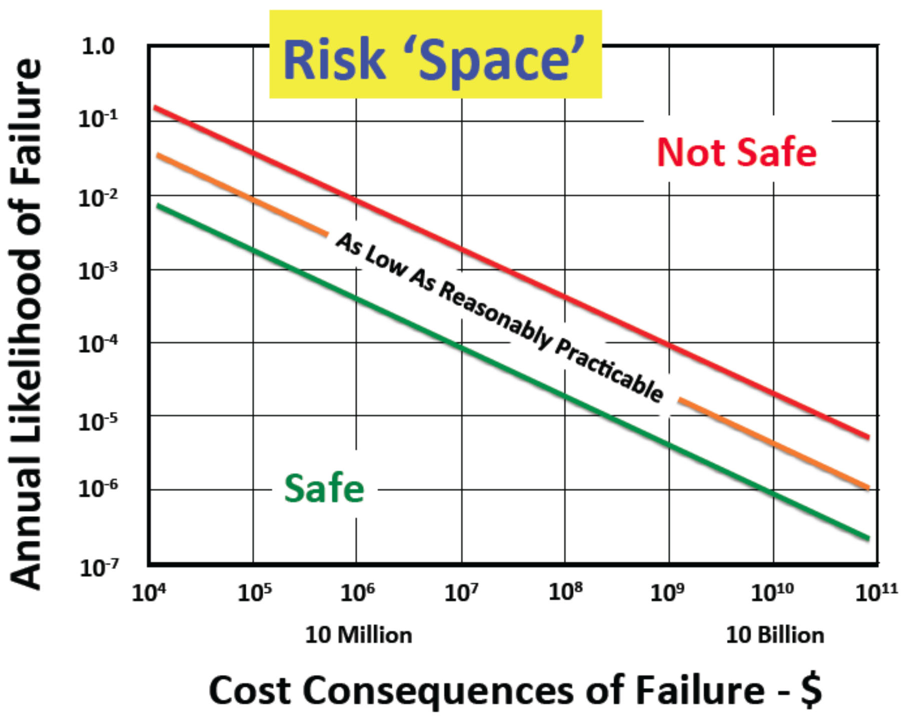

Figure 1: The Likelihood and Consequences of Major Accidents define the Risk Space combined with definition of ALARP Risks to determine Safe and Not Safe Risks.

The Risk Space is divided into two categories of Risks: 1) 'Safe[3]' – Fit-for-Purpose, and 2) 'Not Safe' – Not Fit-for-Purpose. The diagonal lines defining the Safe and Not Safe Risks indicate the range of risks defined to be ALARP. This ALARP RAM process is based on a very important premise: As the potential Consequences with System MAEs increase, the Likelihoods of MAEs must decrease.

Definition of ALARP risks can be based on: 1) Historic (experience based) Precedents based on comparable systems that have demonstrated to have risks that are 'tolerable' or 'acceptable'; 2) Economic Cost-Benefit analyses that evaluate initial and long-term present-valued monetary costs developed during operation of Systems; and 3) Results from current decisions involving projected MAE Risks associated with comparable systems –'Standards of Practice' (Hartford, 2009; Bea 1990, 2000).

To be 'Safe', the MAE Risk associated with a System should be below the lower limit of the ALARP 'Risk zone.' If during the 'life-cycle' of a System, the MAE Risk increases above the 'upper limit' of the ALARP 'Risk Zone', operations associated with the System should stop until the System has been modified and the modifications validated before the System is placed back in operation.

Definition of ALARP Risks should involve collaborative interactions of representatives from the four communities defined previously (Industry, Government, Public, Environment). Such collaborative interactions are characterized as a 'Technology Delivery System' (Wenk, 2011).

The range of ALARP Risks identified in Figure 1 are based on previous assessments of offshore exploratory drilling and production systems comparable to those proposed for the BP GAB exploratory drilling (Bea 1990, 1991, 2000, 2010; Delmar Engineering, 2011). This range of ALARP MAE Risks must be confirmed by the future deliberations proposed herein.

A Case-Based Analysis of results from a 10-year duration effort associated with seven organizations that attempted to develop ALARP MAE Risks associated with offshore and onshore petroleum exploration and production Systems identified five categories of factors

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3 Safe – "Freedom from undue exposure to injury or harm." (Bea, 2016)

associated with successful ALARP MAE Risk Systems. These five categories were identified as the '5 Cs' Bea (1999b, 2010, 2011):

1) **Commitment** - by all Organizations and Operating Groups involved in development and implementation of ALARP MAE Risks – continuous 'Top-Down and Bottom-Up,' 'Board of Directors and 'Deck Plate Operators.'
2) **Capabilities -** Organizations and Operating Groups' technical, operational and management personnel have the abilities to properly and effectively address ALARP MAE Risk performance characteristics before, during, and after operations of a System – effectively utilizing Proactive, Interactive, and Reactive RAM processes;
3) **Cognizance** – an acute awareness by the Systems' Operating Groups and Organizations of the primary hazards (threats) that pose the Risks of MAEs.
4) **Cultures** – Organizations and Operating Groups shared beliefs, values, norms, feelings, artifacts, and resources having a primary goal of developing ALARP MAE Risks before, during, and after operations of a System – a 'Safety Culture' (Gale, 2011: Transportation Research Board, 2016).
5) **Counting** – valid and validated quantitative measures of MAE Risks during the life-cycle of the System and the Costs and Benefits resulting from development and maintenance of Systems having ALARP MAE Risks.

Experience with these organizations demonstrated that ALL '5 Cs' must be effectively developed and maintained throughout the life-cycle of a given System. If any one or more of the '5 Cs' were missing or defective, then failure of the efforts and Systems could be expected. The organizations and operating groups that effectively developed and maintained all of the '5 Cs' were characterized as Higher Reliability Organizations having Higher Reliability Management and Systems (Bea, 2011).

One of the most important of the '5 Cs' is Counting. Counting includes explicit up-front analyses of the MAE Risks and monetary Costs and Benefits associated with development, implementation, and maintenance of Systems MAE RAM processes. The quantitative MAE Risks must be valid and validated (NOPSEMA, 2012, 2013). Development and maintenance of effective System MAE RAM processes and procedures cost substantial amounts of money and other important organizational resources. However, if System RAM processes and procedures are effective, there are no (or vastly reduced numbers of) future MAEs; and, if they do occur, the Consequences are greatly reduced. Safety and Reliability can be 'good business' if there is a sustained 'long-term' focus on development of acceptable profitability.

There is a natural tension between "Production" (i.e., measured growth and profitability that are sensitive to costs) and "Protection" (resources invested to prevent failures – that do not happen – and that are difficult to "measure" until they happen). If this tension is not properly addressed, then experience has clearly demonstrated that organizations can expect to develop undesirable over-emphasis on System Production (readily measured) and under-emphasis on System Protection (not readily measured). Sufficient industrial 'profitability' provides essential monetary resources required for successful System MAE RAM processes (Bea, 2000, 2002a).

Exploratory Drilling Uncontrolled Blowout Risk

Currently available documentation and experience associated with comparable offshore exploratory drilling Systems has been used to perform a QRA to evaluate the MAE Risk of an Uncontrolled Blowout during the proposed BP GAB 2016 exploratory drilling projects – Stromlo-1, and Whinham-1. The results are summarized in Figure 2.

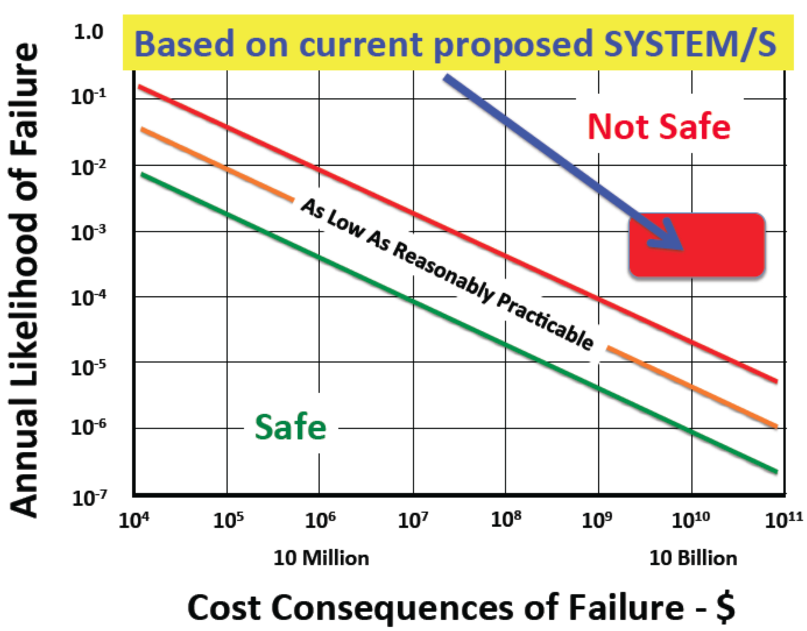

Figure 2: The Risk/s of an uncontrolled blowout associated with the currently proposed BP GAB exploratory drilling Systems.

Likelihood of an Uncontrolled Blowout

Statistics published by the International Association of Oil and Gas Producers (OGP) on blowout frequencies (International Association of Oil and Gas Producers, 2010) in "Operations of North Sea Standard" indicate Likelihoods of Uncontrolled Blowouts associated with deep water exploratory drilling in the range of 2 x 10^{-3} (2/1,000) to 3 x 10^{-4} per wells drilled per year. Thirty-nine percent of the Uncontrolled Blowouts were subsea. This range of Likelihoods was confirmed by results contained in BP's Major Accident Risk (MAR) Process guidelines (BP, 2008b).

An important premise underlying these results is that the BP GAB exploratory drilling Systems will be comparable with those used in exploratory drilling in the U.K. and Norwegian Sectors of the North Sea. Both of these Sectors are regulated based on Safety Case Regime 'type' processes (Khorsandi, 2011). In addition, the drilling 'environments' (e.g. petroleum geology, meteorological – oceanographic, operating conditions) are comparable (Bight Petroleum, 2015; GEOEXPro, 2015).

Relative to this QRA, this premise means the BP GAB exploratory drilling Systems have been evaluated to possess operational safety and reliability characteristics equivalent to those in the two North Sea Sectors. The BP, Diamond Offshore Great White, and other organizations involved in the operations associated with the proposed BP GAB exploratory drilling Systems have been evaluated to have effective operational 'Safety Cultures' (Transportation Research Board, 2016; Gale 2011) comparable with those in the U.K. and Norwegian Sectors of the North Sea. This premise must be validated before the results in this submission can be relied upon.

Consequences of Uncontrolled Blowout

The second important premise integrated into the results summarized in Figure 2 is the range of petroleum discharges associated with an uncontrolled blowout. The 'lower range' and 'upper range' have been based on two scenarios identified in the document submitted to this Senate Committee by Lebreton (2015) – identified as '2B' ('Pessimistic') and '2A' ('Optimistic'). The total discharges evaluated by Lebreton were 4.35 and 0.435 million barrels of petroleum, respectively. The spill results published by BP (2016a) indicates the results published by Lebreton are 'optimistic.'

None of the discharge estimates reviewed during this QRA have included the volumes of petroleum gases released to the atmosphere during an uncontrolled blowout (Azwell et al, 2011).

Scenario '2B' is based on a discharge rate of 50,000 barrels per day (bbl/day) and 87 days to cap the well. Scenario '2A' is based on a discharge rate of 5,000 bbl/day and 35 days to cap the well.

The scenario '2B' discharge rate is comparable with that experienced during the Macondo well blowout (52,700 to 62,200 bbl/day) (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011a, 2011b; . The scenario '2A' discharge rate is comparable with that experienced during the blowout of the Montara well in the Timor Sea (2,000 to 3,000 bbl/day) (Montara Commission of Inquiry, 2010).

The '2A' 'Optimistic' case is based on 35 days to stop the flow with the successful use of a capping stack as evaluated by BP (BP, 2016b, 2016c). BP purports that this duration is the "most credible worst case scenario." The '2B' 'Pessimistic' case is based on 87 days to stop the flow with the successful use of a capping stack. The 87 days to stop the flow is based on the time BP needed to stop the flow from the Macondo well in the Gulf of Mexico (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011a).

BP has estimated that it would take 158 days to drill a relief well at the proposed GAB exploratory drilling locations (BP, 2016b, 2016c). BP required 152 days to drill a successful relief well at the Macondo Gulf of Mexico well location (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011a). PTT Exploration and Production required 74 days to drill a successful relief well at the Montara wellhead platform (Montara Commission of Inquiry, 2010).

A third important premise integrated into the results summarized in Figure 2 are the 'Costs' associated with the 'Optimistic' '2A' and 'Pessimistic' '2B' uncontrolled blowout discharges. The study submitted to this Senate Committee performed by Ellis (2016) involved detailed analyses of the fate of the released petroleum (oil) (Lebreton, 2015). Two seasons (summer, winter) and four spill scenarios were considered. The spill scenarios were based 'first-principles' based analytical models that incorporated different release locations, release durations, discharge rates, and crude oil types. Computational analytical models were used to evaluate the environmental forcing (e.g. wind, waves, currents), physical and chemical changes (e.g. advection, dispersion, evaporation), spill trajectories, and beaching processes.

Ellis concluded (2016): *"This document has presented an analysis of the Matters of National Environmental Significance (MNES) that are relevant under the Commonwealth Environment Protection Biodiversity Conservation Act (1999) within BP's proposed exploratory drilling areas and in extensive areas that may be impacted in the event of oil spills as modeled in the document entitled "Stochastic analysis of deep sea oil spill trajectories in the Great Australian Bight" (LeBreton 2015). The analyses revealed that there are several hundred MNES that pose serious constraints to BP's project proposal."*

Ellis concluded both Summer and Winter Oil Spills (2A Scenario) affected several hundred important species and 36 Commonwealth Marine Areas, Regions and Reserves (Ellis, 2016): *"The results of my study speak for themselves. Oil spills in either summer or winter lead to widespread impacts on biodiversity that extend from Western Australia to Tasmania and beyond to the south-east coast and potentially New Zealand."*

The U.S. Environmental Protection Agency (EPA) 'Basic Oil Spill Cost Estimation' developed by Etkin (2004) was used in this QRA to determine the Costs (U.S. 2000 Dollars, $) of an Uncontrolled Blowout at the two proposed BP GAB drilling locations. These Costs include response costs and environmental and socioeconomic damages (Etkin 1999, 2000, 2004). The EPA Model incorporates spill-specific factors that influence Costs – spill amount; oil type; response methodology and effectiveness; impacted medium; location-specific socioeconomic value, freshwater vulnerability, habitat/wildlife sensitivity; and location type.

Application of the EPA Model resulted in a 'Low Impacts' Cost of $5,000 per barrel of oil spilled and a 'High Impacts' Cost of $20,000 per barrel of oil spilled. Very High Impacts Costs exceeded $40,000 per barrel of oil spilled. Given current estimates of the total Costs associated with the BP Macondo well blowout of approximately U.S. $80 - $100 Billion and a total spill volume of 4 – 5 million barrels, results in a Cost of $20,000 per barrel of oil spilled. These total Cost ranges were corroborated with the empirical analyses of historic oil spill costs by Kontovas et al (2010).

The '2A' GAB spill scenario (0.435 million barrels) and a 'Low Impacts' cost of $5,000 per barrel results in a total Cost of $2.2 Billion. The '2B' GAB spill scenario (4.35 million barrels) and a 'High Impacts' cost of $20,000 per barrel results in a total Cost of $87 Billion. These two uncontrolled blowout spill Costs are shown in Figure 2.

If the '2B'GAB spill scenario (50,000 bbl/day) were based on 158 days to drill a relief well as evaluated by BP, the total discharge would be 7.9 million barrels. At a Cost of $20,000 per barrel of oil spilled, this '2B+' scenario would result in a total Cost of $158 Billion.

Uncontrolled Blowout Risk

These QRA results based on the proposed BP GAB exploratory drilling Systems indicate the Risk of an Uncontrolled Blowout during exploratory drilling is not ALARP (NOPSEMA, 2015b; Hartford, 2009). Both the assessed Likelihood and Consequences exceed historic performance, cost-benefit, and standards-of-practice guidelines for determination of ALARP Risks associated with MAEs (Bea, 1991, 2000, 2010).

Reduced BP GAB Drilling Uncontrolled Blowout Risk

Results from the QRA with two specified additional MAE Risk Mitigation provisions to the currently proposed BP GAB exploratory drilling Systems (Figure 3) indicate the Risk of an Uncontrolled Blowout could be developed to be ALARP if the following provisions are properly developed and implemented:

1) Reduce the Likelihood: Systems Operators and Organizations adopt and maintain additional procedures and processes that will develop Higher Reliability Organizations having Higher Reliability Management and Systems (Bea, 2011; Roe and Schulman 2008, 2011; Carnes, 2011), and
2) Reduce the Consequences: Provisions for emergency controls and mitigations of an uncontrolled blowout during exploratory drilling include mobilization a relief well drilling System that would be staged at a nearby location such that it could arrive on site and be capable of drilling a relief well under anticipated GAB conditions within specified timeframes (Pew Charitable Trusts, 2013). Relief wells have proven to be the ultimate well blowout source control (Harvey, 2014). This relief well activity would be conducted in

parallel with the other source control response techniques proposed by BP (closure of BOP, ROV mobilization to close BOP, Capping Stack deployment) (BP 2016b, 2016c).

An alternative to the nearby relief well System would be to have an on-site (nearby) relief well System whose simultaneous drilling progress 'lags behind' the primary drilling system enabling use of experience and information developed by the primary drilling System allowing reliable rapid closure of the blowout well (Harvey, 2014).

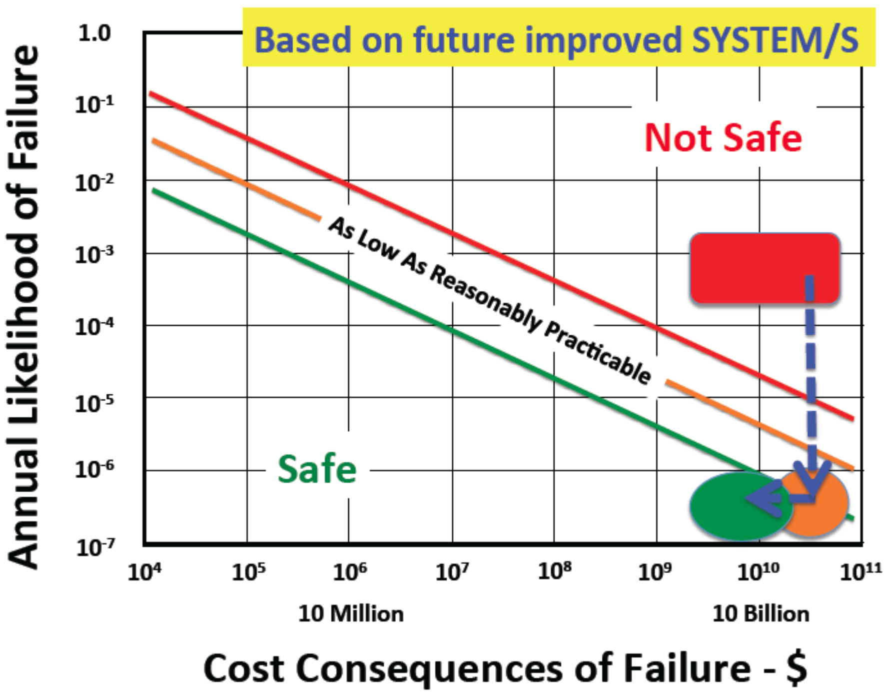

Figure 3: The Risk of an uncontrolled blowout associated with two specified improvements to the BP GAB exploratory drilling Systems.

Reduction of the Likelihood of an uncontrolled blowout to develop ALARP Risk requires the exploratory drilling System proposed by BP probability of failure (blowout not prevented) be reduced by a factor of approximately 1,000. Such reductions have proven to be possible for offshore oil and gas exploration and production Systems given the System performance characteristics are: "Outstanding, exceeding all standards and requirements" (Bea, 2000, 2002b). System Risk 'Auditing' Instruments have been developed and validated that can be used to assure that such Likelihood reductions have been developed (Bea, 2000, 2002a, 2002b).

Reduction of the Consequences of an uncontrolled blowout to develop ALARP Risk requires that given an uncontrolled blowout with a spill rate of 5,000 barrels per day, the BP GAB exploratory drilling System must be able to stop the blowout within a period of approximately 35 days – the time estimated by BP to deploy a Capping Stack located in Singapore – or within a period of 149 days to drill a relief well (BP, 2016b, 2016c).

However, if the spill rate were 50,000 barrels per day, the BP exploratory drilling System must be able to stop the blowout within a period of approximately 35 days. If the Capping Stack were located onboard an undamaged (by the blowout) Diamond Drilling Ocean Great White 'primary' drilling unit, and if the Capping Stack could be successfully deployed, the blowout could be stopped in such a period. Experience in the Gulf of Mexico with deployment of a nearby shore-based Capping Stack to stop a blowout indicates a successful deployment could be accomplished in approximately 15 days (Marine Well Containment Company, 2012).

The only other option to stop a blowout with such a high spill rate would be for the BP exploratory drilling System to include another relief well drilling System located nearby (Pew Charitable Trusts, 2016). The relief well would be started after the primary well was started. The relief well drilling System's progress would 'lag behind' the primary drilling System so the relief well drilling System could take advantage of the experience and data gathered by the primary drilling System. In this case, the nearby relief well drilling System would be able to rapidly close on the blowing out well and stop the flow. This relief well drilling System would need to have the same 'means and measures' as the primary drilling System so as not to increase the Likelihood of an uncontrolled blowout.

If no other practical options for rapid and reliable closure of a blowout well with a spill rate of 50,000 barrels per day could be determined, then ALARP Risk guidelines indicate the exploratory drilling should not be permitted until it could be demonstrated the Consequences could be effectively reduced so as to result in ALARP Risk.

Reduced Likelihood of Uncontrolled Blowout

High Reliability Systems

Experience with offshore oil and gas exploration and production Systems has shown the single most important and essential element in effective Systems RAM is creating, developing, and maintaining collaborative enterprises of High Reliability Organizations (Roberts 1989), with

High Reliability Management (Roe and Schulman, 2008, 2011), and with High Reliability Governance (Carnes, 2011) that develop and maintain High Reliability Systems (Bea 2010, 2011). Healthy and productive industry requires equally healthy and productive governance (Carnes, 2011). If these three components are not present, then one can expect significant problems in realizing Systems that have ALARP MARs. Development of high reliability systems must effectively integrate the industrial and governmental components (high reliability governance) and the owner – operator and sub-contractor components (high reliability organizations) to develop an effective collaborative enterprise enabling realization of high reliability systems.

Properly assessing the consequences of failures – before the failures develop – is very important. Experience shows the single dominant tendency is to underestimate the true consequences of potential failures. The system operators and organizations think they are prepared to handle failures, but when the failures happen, the responses clearly show the thinking and preparations were seriously deficient. The underestimates in the consequences of failures result from a wide variety of deficiencies in the assessment processes (e.g., not recognizing long-term and off-site negative impacts effects on the public, governments, industry, and environment). Frequently, important things are simply left out and there are major flaws embedded in the assumptions concerning controllability of the consequences. In the face of evidence to the contrary, we hope that things will work as they should and the consequences will be low. Failures frequently develop because of the tendency to underestimate the consequences of failure coupled with the consequent tendency to improperly manage the consequences associated with an engineered system; the system is not properly prepared to deal with the potential consequences of the potential failures it faces.

Studies of HRO (Higher Reliability Organizations) have shed some light on the factors that contribute to errors made by organizations and risk mitigation in HRO. HRO are those organizations that have operated nearly error free over long periods of time. A wide variety of HRO have been studied over long periods of time. The HRO research has been directed to define what these organizations do to reduce the probabilities of serious errors. The work has shown that the reduction in error occurrence is accomplished by the following (Roberts, 1989, 1993; Weick, 1995; Weick, et al, 1999): 1) Command by exception or negation, 2) Redundancy (robustness – defect and damage tolerance), 3) Procedures and rules, 4) Selection and training, 5) Appropriate rewards and punishment, and 6) Ability of management to 'see the big picture'.

Command by exception (management by exception) refers to management activity in which authority is pushed to the lower levels of the organization by managers who constantly monitor the behavior of their subordinates. Decision making responsibility is allowed to migrate to the persons with the most expertise to make the decision when unfamiliar situations arise (employee empowerment).

Redundancy (Robustness) involves people, procedures, and hardware. It involves numerous individuals who serve as redundant decision makers. There are multiple hardware components that will permit the system to function when one of the components fails. The term redundancy is directed toward identification of the need for organizational 'robustness' – damage and defect tolerance that can be developed given proper configuration (deployment), ductility – ability and willingness to shift demands, and excess capacity (ability to carry temporary overloads).

Procedures and rules that are correct, accurate, complete, well organized, well documented, and are not excessively complex are an important part of HRO. Adherence to the rules is emphasized as a way to prevent errors, unless the rules themselves contribute to error.

Selection and training - HRO develop constant and high quality programs of personnel selection and training. Personnel selection is intended to select people that have natural talents for performing the tasks that have to be performed. Training in the conduct of normal and abnormal activities is mandatory to avoid errors. Training in how to handle unpredictable and unimaginable unraveling of systems is also needed. Establishment of appropriate rewards and punishment that are consistent with the organizational goals is critical; incentives are a key to performance.

HRO organizational structure is defined as one that allows key decision makers to understand the big picture. These decision makers with the big picture perceive the important developing situations, properly integrate them, and then develop high reliability responses.

In recent organizational research performed by Libuser (1994), five prominent failures were addressed including the Chernobyl nuclear power plant, the grounding of the Exxon Valdez, the

Bhopal chemical plant gas leak, the mis-grinding of the Hubble Telescope mirror, and the explosion of the space shuttle Challenger. These failures were evaluated in the context of five hypotheses that defined risk mitigating and non-risk mitigating organizations. The failures provided support for the following five hypotheses:

1) Risk mitigating organizations have extensive process auditing procedures. Process auditing is an established system for ongoing checks designed to spot expected as well as unexpected safety problems. Safety drills would be included in this category as would be equipment testing. Follow- ups on problems revealed in prior audits are a critical part of this function.
2) Risk mitigating organizations have reward systems that encourage risk mitigating behavior on the part of the organization, its members, and constituents. The reward system is the payoff that an individual or organization gets for behaving one way or another. It is concerned with reducing risky behavior.
3) Risk mitigating organizations have System Quality Standards that exceed the referent standard of Quality in the industry.
4) Risk mitigating organizations correctly assess the System Risk associated with the given problem or situation. Two elements of risk perception are involved. One is whether or not there was any knowledge that risk existed at all. The second is if there was knowledge that risk existed, the extent to which it was understood sufficiently.
5) Risk mitigating organizations have a strong Command and Control system consisting of five elements: a) migrating decision making, b) redundancy, c) rules and procedures, d) training, and e) senior management has the big picture.

These concepts have been extended to characterize how organizations can organize to achieve high quality and reliability. Effective HRO's are characterized by (Weick, Sutcliffe, Obstfeld, 1999; Weick, Quinn, 1999; Weick, Sutcliffe, 2001):

1) **Preoccupation with failure** – any and all failures are regarded as insights on the health of a system, thorough analyses of near-failures, generalize (not localize) failures, encourage self-reporting of errors, and understand the liabilities of successes.
2) **Reluctance to simplify interpretations** – regard simplifications as potentially dangerous because they limit both the precautions people take and the number of undesired consequences

they envision, respect what they do not know, match external complexities with internal complexities (requisite variety), diverse checks and balances, encourage a divergence in analytical perspectives among members of an organization (it is the divergence, not the commonalties, that hold the key to detecting anomalies).

3) **Sensitivity to operations** – construct and maintain a cognitive map that allows them to integrate diverse inputs into a single picture of the overall situation and status (situational awareness, 'having the bubble'); people act thoughtfully and with heed, redundancy involving cross checks, doubts that precautions are sufficient, and wariness about claimed levels of competence; and exhibit extraordinary sensitivity to the incipient overloading of any one of it members - sensemaking.

4) **Commitment to resilience** – capacity to cope with unanticipated dangers after they have become manifest, continuous management of fluctuations, prepare for inevitable surprises by expanding the general knowledge, technical facility, and command over resources, formal support for improvisation (capability to recombine actions in repertoire into novel successful combinations), and simultaneously believe and doubt their past experience.

5) **Under-specification of structures** – avoid the adoption of orderly procedures to reduce error that often spreads them around; avoid higher level errors that tend to pick up and combine with lower level errors that make them harder to comprehend and more interactively complex, gain flexibility by enacting moments of organized anarchy, loosen specification of who is the important decision maker in order to allow decision making to migrate along with problems (migrating decision making); and move in the direction of a garbage can structure in which problems, solutions, decision makers, and choice opportunities are independent streams flowing through a system that become linked by their arrival and departure times and by any structural constraints that affect which problems, solutions and decision makers have access to which opportunities.

Reason (1997) in expanding his work from the individual (Reason, 1990) to the organization, develops another series of important insights and findings about HROs. Reason observes that all technological organizations are governed by two primary processes: Production and Protection. Production produces the resources that make protection possible. Thus, the needs of Production will generally have priority throughout most of an organization's life, and consequently, most of those that manage the organization will have skills in production, not Protection. It is only after an accident or a near-miss that Protection becomes for a short period time paramount in the minds of those that manage an organization. Reason observes that Production and Protection are dependent on the same underlying organizational processes. If priority is given to Production by management and the skills of the Organization are directed to maximizing Production, then unless other measures are implemented, one can expect an inevitable loss in Protection until significant accidents cause an awakening of the need to implement Protective measures. The Organization chooses to focus on problems that it always has (Production) and not on problems it almost never has (major failures and disasters). The organization becomes 'habituated' to the risks it faces and people forget to be afraid: "*chronic worry is the price of Quality and Reliability*" (Reason, 1997).

Organizations do not exist in isolation; they influence other organizations and are influenced by other organizations. Many high consequence failures of engineered systems involve malfunctions that develop in multiple organizations having different responsibilities for different parts of a given system. In this work, the interactions among different organizations has been cast in the framework of a Technology Delivery System (TDS) (Wenk 2011). A TDS consists of four fundamental components: the public, the governmental organizations (local, state, national, and international), commercial and industrial organizations, and the environment (generally represented by environmental advocate organizations). The function of a TDS is to apply scientific and engineering knowledge to develop and deliver goods, services, and resources needed by a society. A TDS models reality with inputs of knowledge, fiscal, natural, and human resources synchronized by a network of communications. Outputs are both intended and unintended. The system is driven and steered by three operating instructions—market place economics, public policies, and social norms.

In the case of system failures, malfunctions in the TDS have often developed at the interfaces and interactions between the commercial – industrial component and the governmental component. The government component empowers the industrial component to develop goods, services, and resources by and for the public. The government is charged with oversight of the industrial activities: with defining the goals and objectives of the industrial activities and with assuring that these goals and objectives are realized to serve the public interests and protect the environment. The industrial component is also responsible to the public in the form of shareholders who help provide financial capital to maintain and develop the commercial – industrial enterprise. Major failures of engineered systems frequently have developed because of severe, long-term breakdowns in collaborations between the industrial and governmental components (Reason, 1997). These breakdowns are exacerbated when the governmental component merges its goals with those of the industrial component. High Reliability Governance is not developed (Carnes, 2011). Severe conflicts are developed between the public governmental responsibilities and the commercial industrial responsibilities and which result in failures of the engineered systems. Similar breakdowns develop when the capabilities and behaviors of either of the components are not able to constructively collaborate to assure that the goals and objectives of the four TDS components are well served. There must be comparable 'strengths' and 'capabilities' in the industrial and governmental components and these must work in responsible and collaborative ways for the goals of quality, reliability, and ALARP MAE Risks to be realized.

The issues and questions raised by Hopkins in his submission to this Senate Committee (Hopkins, 2016) are indicative of a potential BP GAB exploratory drilling System that is far from the High Reliability System required to develop ALARP blowout Risk. These issues and questions are very similar to those that were deliberated by BP and the U.S. Management Service before, during, and after the Deepwater Horizon Macondo well blowout in the Gulf of Mexico (Bea, 2011b). These issues and questions need to be addressed and the concerns effectively mitigated before exploratory drilling is permitted in the GAB.

Well Control System

The primary goal of a Well Control System is to maintain the pressure inside a drilled well so as to prevent influx of gas or fluids and escaping to the surface in an uncontrolled manner. Effective 'Layers of Protection' are required to prevent and mitigate well control issues. These Layers of Protection have been defined in the report by The PEW Charitable Trusts (2013), by Prichard and Lacy (2011), and further detailed in the series of documents by Pritchard (2011a, 2011b, 2011c, 2016).

High Strength Bolted Connections

High Reliability Systems are characterized as having six fundamental characteristics (Bea, 2010):

1) **Serviceability** – ability to satisfy purposes for intended conditions,
2) **Safety** – free from undue threats of harm to life and the environment,
3) **Durability** – free from unexpected maintenance and degradations in the performance characteristics of the System,
4) **Compatibility** –acceptable economic, time, environmental, political, social, and aesthetic characteristics,
5) **Resilience** – acceptable time required to re-establish performance of a System after it has been disrupted, and
6) **Sustainability** - ability of a System to provide its intended goods and services with desirable Quality and Reliability.

Provision of System Robustness (defect or damage tolerance), design for constructability, and design for IMR (Inspection, Maintenance, Repair) are critical aspects of engineering Systems that will be able to deliver acceptable Quality and Reliability (Bea, 2006). Design of the System to assure Robustness combines the beneficial aspects of configuration, ductility, excess capacity, and appropriate correlation (it takes all four). The result is a defect and damage tolerant System that is able to maintain its quality characteristics while in service. This has important ramifications with regard to engineering system design criteria, guidelines, and practices which have been directed toward development of 'cost-optimized' systems – minimum CapEx systems. Effective 'back-ups', frequently referred to as 'redundancy', are removed to reduce first costs. In the process, damage and defect intolerant systems are developed. When these systems are challenged with unexpected uncertainties, defects, and damage, they are not able to perform acceptably and failures are developed.

Recently, the offshore oil and gas industry and regulatory agencies have become very concerned about High Strength Bolted Connections incorporated into many critically important equipment components, e.g. blowout preventers, marine risers (U.S. Department of the Interior, Bureau of Safety and Environmental Enforcement, 2016. The U.S. Department of the Interior Bureau of

Safety and Environmental Enforcement (BSEE) alerted the offshore oil and gas industry about this concern beginning in 2003. The concern became a major concern in 2012 when there was a global recall of the bolts associated with connector bolts provided by a specified manufacturer. In January 2016, BSEE wrote to the American Petroleum Institute: “This is a systematic industry problem that requires immediate attention.”

Manufacturers of the safety critical pieces of equipment have identified multiple factors involved in the high strength bolt connector failures including steel hardness, thread machining defects, corrosion protection, and tightening of the bolts. At this time, there has not been any industry-wide resolution of this problem.

Given what has been learned about development of High Reliability Systems, the long-term (2003 – 2016), pervasive nature of this high strength bolted connector problem in safety-critical equipment used in deepwater drilling Systems should be effectively resolved before proceeding with the proposed BP GAB drilling program.

Reduced Consequences of Uncontrolled Blowout

The primary way to reduce the Consequences of an uncontrolled blowout addressed in this QRA is by reducing the volume of oil spilled (and, all other toxic hydrocarbon reservoir fluids and gases). The volume of oil spilled is dependent on the rate of flow at the time of the blowout and the time required to stop the flow.

BP has proposed a combination of four blowout source control response techniques that would be used in sequence (BP, 2016b): (1) closure of the blow out preventer (BOP), (2) Remote Operated Vehicle (ROV) intervention with the BOP, (3) deployment of a Capping Stack, and (4) drilling a relief well. Each of these techniques requires different times to complete: 35 days for a Capping Stack and 149 days for a relief well. Each of these techniques has a different likelihood of success.

For low blowout flow rates (e.g. 5,000 barrels per day), this QRA indicates the four blowout source control response techniques proposed by BP could stop the flow soon enough so as to reduce the Consequences sufficiently to satisfy ALARP Risk requirements.

For high blowout flow rates (e.g. 50,000 barrels per day), this QRA has addressed two options: 1) utilization of a second nearby drill rig that could be quickly mobilized to the blowout location ('Same Season' relief well) to stop the flow within a specified time (e.g. 35 days), and 2) simultaneous drilling of a 'lagging' relief well that could be rapidly advanced to close with and seal the blowout well. The 'Same Season' relief well option was formally required by the U.S. Department of Interior (2015) for exploratory drilling on the U.S. Arctic Outer Continental Shelf. The 'Same Season' relief well option was used during 2015 by Shell in exploratory drilling of the Burger Prospect in the Chukchi Sea, Alaska (Shell, 2013).

Uncontrolled Blowout Risk

Results from the QRA with specified additional MAE Mitigation provisions to the currently proposed BP GAB exploratory drilling Systems indicate the Risk of an Uncontrolled Blowout could be developed to be ALARP if these provisions are properly developed and implemented.

Recommendation

To assist NOPSEMA and this Senate Committee determination that the Systems utilized in the BP GAB exploratory drilling program and future GAB exploratory drilling programs can and will develop ALARP Risk associated with an uncontrolled blowout, it is recommended NOPSEMA develop and appoint an Expert ALARP Risk Panel comprised of experienced, qualified individuals representing four concerned constituencies: 1) the Australian governments, 2) the Australian public, 3) the Australian and International oil and gas industry organizations, and 4) the organizations representing maintenance of environmental quality. This Expert ALARP Risk Panel would be charged with development of a summary report submitted to this Senate Committee and NOPSEMA. The industry representatives should include experts with extensive experience in drilling engineering and operations, blowout source control, and Risk Assessment & Management.

Conclusion

If the Senate Committee would like to discuss these findings and recommendation, the author would be privileged to appear before the inquiry via telephone or video conference.

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Biographical Summary – Robert 'Bob' Bea

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Experience

1954-1959: U. S. Army Corps of Engineers, Engineer-in-Training
1959-1960: S. S. Jacobs Construction Co., Construction Estimator
1960-1976: Shell Oil Company (Offshore drilling and production operations – southern Louisiana; Manager, Head Office Offshore Civil Engineering Group; Chief Mechanical Engineer, Bakersfield Production Division; Offshore Delta Division Construction Engineer; Head Office Production & Financial Control; Royal Dutch Shell Ltd. Production, Engineering & Financial Control; Shell Development Company, Manager, Offshore Technology Development Group
1976-1981: Ocean Services Division, Woodward-Clyde Consultants (Vice President, Chief Engineer, Geotechnical, Structural, Environmental, Field Engineering Operations, Ocean – Offshore Engineering projects in 72 countries including Australia and New Zealand)
1981-1989: PMB Engineering - Bechtel Inc. (Vice President, Senior International Consultant, Ocean – Offshore Engineering Operations Gulf of Mexico, U.S. Pacific Coast, U.S. Beaufort and Chuckchi Sea, Canadian Arctic and East Coast, and Australian Norwest Shelf, Timor Sea, and Bass Straits developments)
1989 - 2012: University of California Berkeley (Professor, Naval Architecture & Offshore Engineering, Civil & Environmental Engineering, Engineering & Project Management)
2012 - : Professor Emeritus, University of California Berkeley, Marine Technology Development Group, Center for Catastrophic Risk Management

Background

I have devoted the past 25 years of my professional career to research associated with the Risk Assessment and Management (RAM) and the catastrophic failure of engineered systems. This work has involved detailed studies and investigations of more than 630 major accidents, failures, and disasters associated with complex engineered systems such as the Occidental Piper Alpha platform in the North Sea, the Exxon Valdez tankship, the Petrobras P36 floating production platform offshore Brazil, the NASA Columbia space shuttle, and the flood protection system for the Greater New Orleans Area during Hurricane Katrina. The research has focused primarily on interactions of engineering and organizational–institutional processes associated with catastrophic failures. A primary objective of this work has been development, validation, and application of advanced methods for RAM of complex engineered systems during their life-cycles (concept development through decommissioning). I have published 280 refereed journal and conference papers that chronicle the studies and research I have performed that address RAM of complex engineered systems for offshore platforms, pipelines, and floating facilities for oil and gas exploration and production. I have written 3 books and 10 chapters in textbooks that document this background. I have been recognized for my contributions to the RAM of offshore oil and gas exploration and production engineered systems by the U.S. Minerals Management Service, the Offshore Technology Center, the Society of Petroleum Engineers, the American Society of Mechanical Engineers, the American Society of Civil Engineers, the Society of Naval Architects and Marine Engineers, the Academy of Management, and the National Research Council Academy of Engineering.

During 1989 – 2001, I completed requirements for the Doctor of Philosophy degree from the University of Western Australia. My research was conducted under the auspices of the Center for Oil and Gas Engineering and resulted in my dissertation titled: *Human & Organizational Factors in Design & Reliability of Offshore Structures*. In 1989, I was selected as the Eminent Speaker for the Institution of Engineers, Australia. My lecture series resulted in the 1990 IEA publication titled: *Reliability Based Criteria for Coastal and Ocean Structures*. Background from these two publications were incorporated into two text books that I utilized in my graduate courses at the University of California: *Margins of Quality for Engineered Systems, and Human and Organizational Factors: Risk Assessment & Management of Engineered Systems.*

In 1960, I was employed by Shell Oil Company as a coastal - offshore engineer. For the first two years, I worked as a roughneck and roustabout on drill rigs and production platforms located offshore southern Louisiana. During my career with Shell Oil Company, Shell Development Company and Royal Dutch Shell Company, I worked in exploration, drilling, production, refining, transportation, engineering, construction, operations, and research at various locations around the world. I was Chief Offshore Civil Engineer and Manager of the Central Engineering Division for Shell Oil Company located in New Orleans, Manager of the Marine Technology Research Group at Shell Development Company located in Houston, Texas, Chief Engineer in the Bakersfield California Production District, and Head of the Marine Technology Development Group – Central Offshore Engineering Division located in Houston, Texas.

In 1977, I was appointed vice president and chief engineer of an international consulting engineering and contracting company - Woodward-Clyde Ocean Services (now United Research Services - URS Corporation) providing coastal and offshore engineering services to the international offshore oil and gas industry, including hurricane forecasting, development of reliability based design criteria for offshore platforms and pipelines, geotechnical – foundation engineering, structural engineering, construction engineering and design of flood protection facilities for refineries and chemical processing plants along the Gulf coast.

In 1981, I founded the Ocean Engineering Services Division of PMB and became vice president and senior international consultant for PMB – Bechtel. The Ocean Engineering Services Division offered a wide variety of engineering services world-wide that included concept development, design, construction, maintenance, and decommissioning of marine systems including offshore platforms, pipelines, and floating facilities. Of particular importance was work performed by this Division in arctic and sub-arctic areas in development and testing of innovative oil and gas exploration and production systems to work in this challenging environment. This work included development of risk and reliability based engineering design, construction, operation, and maintenance criteria for these systems. This work involved extensive engineering consulting and field exploration studies for Sohio – BP on the North Slope – Prudhoe Bay, Alaska and for Woodside Energy on the Northwest Shelf of Australia.

As I made a career transition from industry to academia in July 1988, I was brought by Occidental Petroleum to Aberdeen, Scotland as a member of an international team to investigate the failure of the Piper Alpha platform. For the next 3 years, the investigation team struggled to understand this disaster. At the end of this experience, I came to understand that for the vast majority of my career I had not understood several important aspects that caused this disaster. These aspects were chiefly focused in the human, organizational, and governance issues that were instrumental in development of the Piper Alpha platform disaster. This experience was reinforced in 1990 when I headed a joint industry – government sponsored project to investigate the grounding of the Exxon Valdez tanker. The investigation of the grounding of the Exxon Valdez taught many of the same lessons we learned from the failure of the Piper Alpha platform. There were some additional lessons that reinforced what I had learned earlier while working for Shell Oil Company as a result of the Unocal Santa Barbara platform blowout, the Shell Bay Marchand platform blowouts, and the Mississippi Piney Woods well blowout – the means, methods, and processes to control, contain and clean up oil and gas in and on the water were very ineffective. This important part of the consequences of failures could not be effectively mitigated.

The Piper Alpha and Exxon Valdez investigations launched a two decade long series of research, development, and consulting projects that addressed different kinds of failures associated with oil and gas exploration and production systems including platforms, ships, and pipelines. All of these studies were conducted as joint industry – government agency sponsored projects. The different kinds of failures included 'quiet failures' that developed during concept development, design, and construction phases – these were projects that suffered serious project 'over-runs' and frequently showed up in legal proceedings. There were also 'noisy system failures' that developed during construction, operations, and maintenance phases – these were projects that received significant media, public and government attention. These different kinds of failures sometimes had similar sources; other times they had different sources. These different kinds of failures had very different 'signatures'. The 'quiet' failures generally were sourced in a few people and a few malfunctions of different parts of a particular system. In contrast, the noisy system failures were sourced in many people and organizations and involved a very large number of malfunctions in many parts of the particular system that generally developed over a long period of time. Examples of the noisy system failures that I investigated during this time period included the Statoil Sleipner A platform sinking (failure during construction), the Texas Tower Number 4 collapse (failure during operation), the sinking of the Petrobras P36 floating production platform, the NASA Columbia shuttle accident, the flood protection system for the Greater New Orleans Area, and the BP Deepwater Horizon Macondo well disaster.

I am co-founder of the Center for Catastrophic Risk Management (CCRM) at the University of California, Berkeley. I organized and help lead the Deepwater Horizon Study Group.