# AY2012-2013



# THE US OIL AND GAS INDUSTRY - A SAFETY CULTURE ENIGMA

In light of the Deepwater Horizon accident, how effective is the Safety Culture within the US Oil and Gas Industry and what insights can be drawn from the Military Aviation community?

**Course Instructor:** 

Dr. Theresa Sabonis-Helf

# **GP CAPT ROBIN H ADLAM RAF UK**

The views expressed in this paper are those of the author and do not reflect the official policy or position of the National Defense University, the Department of Defense or the U.S. Government

Introduction.

On the 20<sup>th</sup> April 2010, an explosion on the Mobile Offshore Drilling Unit (MODU) Deepwater Horizon stationed over the deep water Macondo Prospect oil field in the Gulf of Mexico killed eleven crewmen and resulted in the sinking of the Drilling Unit. This event ushered in an environmental disaster that is now regarded as the second largest in US history, after the 1930's Dust Bowl tragedy, with significant economic consequences that are still impacting BP and the wider oil and gas industry as more stringent regulations come into force. The DEEPWATER HORIZON report to the President of the United States on the Gulf oil disaster<sup>1</sup> highlighted the tragic loss of 11 members of crew and made the following observation on the ecological and financial impact of the disaster:

'The costs from this one industrial accident are not yet fully counted, but it is already clear that the impacts on the region's natural systems and people were enormous, and that economic losses total tens of billions of dollars'

Deepwater Horizon highlighted many leadership challenges and failures within the oil industry, specifically the understanding of risk and the associated safety culture required to mitigate that risk. The challenges facing the oil industry's strategic leadership are considerable especially as the search for oil drives them to explore in ever more demanding locations. Overcoming the challenges will be key to ensure that the raft of recent industry led but government endorsed legislation is observed and that lessons identified from such incidents can be addressed across the full spectrum of the oil and gas industry.

<sup>&</sup>lt;sup>1</sup> Deep Water-The Gulf Oil Disaster and the Future of Offshore Drilling – (Report to the President – National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling – January 2011).

Two key recommendations from the DEEPWATER HORIZON report highlight the issues at the heart of this paper:

- "Deep water energy exploration and production, particularly at the frontiers of experience, involve risks for which neither industry nor government has been adequately prepared, but for which they can and must be prepared in the future."
- "Because regulatory oversight alone will not be sufficient to ensure adequate safety, the oil and gas industry will need to take its own, unilateral steps to increase dramatically safety throughout the industry, including self-policing mechanisms that supplement governmental enforcement"

Due to the contractor and sub-contractor nature of the oil industry, the global reach of oil drilling operations and the multinational involvement of all players involved in oil extraction the challenge facing the strategic leadership of the oil and gas industry is significant<sup>2</sup>. The DEEPWATER HORIZON report identified a fundamental fracture between the strategic leadership at the board-level and operations on the oil rigs at the tactical level and highlights what may be regarded as an example of a failure of the oil and gas industry to nurture a safety culture amongst all tiers of employment. It should be stated at the outset that it is apparent that much is being done in the oil and gas industry to nurture an awareness of safety at the tactical level. This paper will focus on how the leadership is tackling the challenge of the broader 'process safety culture' at the strategic level and offer up a suggested process to address the observation laid out in the National Commission Staff Working paper 21; "Industry and government should investigate other actions and programs that might help promote, sustain, and monitor a culture of safety achievement"<sup>3</sup>.

<sup>&</sup>lt;sup>2</sup> Rigs move between operators and regions, each of which will have differing approaches to safety.

<sup>&</sup>lt;sup>3</sup> National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, A Competent and Nimble Regulator: A New Approach to Risk Assessment and Management, Staff Working Paper No.21.

This paper will examine the challenges of developing and maintaining a safety culture within the US oil and gas industry and, using military aviation safety practices as a benchmark, attempt to offer some observations that may be applicable to the offshore oil and gas industry.

#### Research boundaries.

The oil and gas industry is complex and wide ranging from exploration through distillation to forecourt delivery, consequently this paper will focus on the 'upstream' portion of oil extraction which involves the exploration and production element of the process and the associated strategic leadership required to enable the process. The paper will focus on sea based extraction and associated challenges facing US operators drilling in deep water locations off the shores of the US. It will not examine the strategic economic judgments surrounding a decision to undertake oil extraction or the downstream aspect of oil and gas refinery and distribution.

#### Paper Structure

In order to address the complexity of this topic the paper will approach the challenge in 5 chapters.

- Chapter one will examine the concept of accident theory as it pertains to both the oil and gas
  industry and the military aviation domain in order to identify similarities that warrant further
  comparison. The chapter will also explore how organizations develop effective safety cultures
  required to address these challenges and will include an outline of how they pertain to the
  challenging environments of oil and gas exploration and military aviation specifically the part that
  training plays in developing the culture. The chapter will conclude with a model depicting the
  essence of a safety culture.
- Chapter two will then examine a series of major accidents that have occurred in similarly complex environments and seek to identify the strategic leadership failings in each instance in an attempt to

3

categorize fundamental strategic leadership failings in each case. The aim being to distill the essential elements of strategic leadership within a safety culture and highlight how their absence can result in disaster.

- Chapter three will focus on military aviation (and the military nuclear endeavor) as a comparator to the oil and gas industry. The aim will be to offer observations on how processes employed by the effective strategic leadership of complex military operations may have utility in the commercial sector. The paper will also offer observations on fundamental differences between the two domains that prevent 'absolute' benchmarking; a realization that aspects of the two processes are essentially different.
- Chapter four will then use the essence of a safety culture identified in chapter one to analyze the DEEPWATER HORIZON accident and the associated safety culture of oil and gas industry against the failings listed in chapter two.
- Chapter five will highlight lessons the oil and gas industry can draw from the safety culture inculcated within the military aviation domain.

#### CHAPTER ONE

Establishing a 'safety culture' within large organizations such as the oil and gas industry is no easy task. The challenges facing the strategic leadership are many and varied, so a clear understanding of the benefits that such a culture brings to an organization has to be understood and embraced. Specifically, the leadership will need to understand the inherent risks of any given activity and mitigate accordingly through a robust and sustainable plan that will rely upon a healthy safety culture. This paper will explore the concept of risk and outline the phenomenon of 'incident and accident' events specific to complex organizations. Charles Perrow's framework in his book *Normal Accidents*<sup>4</sup> and the

<sup>&</sup>lt;sup>4</sup> Charles Perrow, Normal Accidents, Princeton University Press, 1999

proponents of a counter point, *High Reliability Theory*, will form the basis to chapter one and will serve as a starting point to identify the similarities between the two distinct activities of oil exploration and military aviation. The chapter will also draw on Professor James Reason's book, *Managing the Risks of Organizational Accidents*.<sup>5</sup> Perrow makes cogent observations on how organizations, through normal operations, become unwitting but key enablers in accident causation. He states that 'human-made catastrophes appear to have increased with industrialization as we built devices that could crash, sink, *burn or explode*' and argues this is due to a phenomenon he calls 'interactive complexity in the presence of tight coupling'<sup>6</sup>. At the other end of the spectrum proponents of High Reliability Theory argue that complex systems, if correctly designed, will compensate for the natural flaws of human endeavor as reflected in James Thompson's book *Organizations in Action*<sup>7</sup>. In order to establish a base line to assess the operational performance of the oil and gas industry the paper will draw on both theories, comparing the two and introduce the concepts of 'complexity' and 'coupling' within system design.

Increasing complexity in systems has been, and remains, an inherent part of system development as man strives to better himself through the industrialized process. E.W.Hagen as one of the editors of 'Nuclear Safety' in 1967 made what appears to be the first analysis of the impact of such complexity through his examination of common-mode failures<sup>8</sup> in the nuclear power field. Here he concludes that the various levels of redundancy built into the system to increase safety had, through greater interdependence, amplified the complexity and reduced the safety of the system. Hagen concludes, "The main problem is complexity itself"<sup>9</sup>. In conjunction with common-mode failures, Perrow highlights two other indications of interaction that increase complexity; proximity of working

 <sup>&</sup>lt;sup>5</sup> James Reason, *Managing the Risk of Organizational Accidents*, (Ashgate Publishing Company, UK – 1997).
 <sup>6</sup> Charles Perrow, *Normal Accidents*, p11.

<sup>&</sup>lt;sup>7</sup> Isoson Theorem Comministration in Astion (New York)

<sup>&</sup>lt;sup>7</sup> James Thompson, *Organizations in Action*, (New York: McGraw-Hill, 1967).

<sup>&</sup>lt;sup>8</sup> Common-mode function exists where one function serves two processes or components.

<sup>&</sup>lt;sup>9</sup> Charles Perrow, Normal Accidents, p73.

units to each other within a system and the dependence of indirect information sources. Such an example of an indirect information source can be found during oil rig operations which rely on indirect pressure feedback loops from the well-head to monitor drilling progress. The oil rig well-head pressure in the drilling process is an indication of drilling progress and any unexpected fluctuations in pressure can indicate a failure in the procedure, but the indication is not definitive and requires expert monitoring and diagnosis. In addition, the oil rig is compelled by its size to position many working parts within close proximity to each other. The failure of any component can directly impact the output of any collocated component even if they are not linked in the output process. Both these phenomenon can be found on aircraft which are further compounded when operated from ship based environments.

Perrow also argues that complex systems demonstrate other characteristics such as the limited ability to isolate failed components and the requirement to undertake production steps in close proximity to other steps. He also highlights the need for personnel specialization which in turn limits individuals' awareness of other aspects of the production cycle; for example, the Remotely Operated Submersible team will have little or no knowledge of the responsibilities of the drilling team. The existence of common-mode connections of components not in the production sequence, but positioned in close proximity of active components, is another key characteristic of a Complex system.

6

In sum, complex systems can be identified by the characteristics identified in the following table:

| Tight spacing of equipment  |  |  |  |  |  |
|---|--|--|--|--|--|
| Proximate production steps  |  |  |  |  |  |
| Many common-mode connections of components not in production sequence |  |  |  |  |  |
| Limited isolation of failed components                                |  |  |  |  |  |
| Personnel specialization limits awareness of interdependence          |  |  |  |  |  |
| Limited substitution of supplies and materials                        |  |  |  |  |  |
| Unfamiliar or unintended feedback loops                               |  |  |  |  |  |
| Many control parameters with potential interactions                   |  |  |  |  |  |
| Indirect or inferential information sources                           |  |  |  |  |  |
| Limited understanding of some processes                               |  |  |  |  |  |

Table 1. Complex Systems<sup>10</sup>

Coupling is a term used to describe the interconnection or interactivity of two or more systems. The more interdependent two items are to, or with, each other, the tighter they are coupled. Loose coupling indicates a level of slack or buffer between two items. *'Tight coupled systems have more timedependent processes, they are more invariant, have little slack and have only one way of achieving the production goal.'<sup>11</sup> As a designer, one must anticipate failure in a tightly coupled system and design in failure modes or redundancies. In loosely coupled systems it is possible to find 'work-rounds' if and when they are required. This does not mean that 'work-rounds' cannot be found in highly coupled systems, Apollo 13<sup>12</sup> is an example, but embracing the concept of failure before it occurs and preparing accordingly will enhance the chance of overcoming disaster. As an example, an exploratory oil well* 

<sup>&</sup>lt;sup>10</sup> Complex System table. Charles Perrow, *Normal Accidents*, p88.

<sup>&</sup>lt;sup>11</sup> Ibid, p93, 94.

<sup>&</sup>lt;sup>12</sup> After the explosion of the No 2 Oxygen tank causing considerable damage to the highly complex and coupled system the crew were able to adapt undamaged systems to ensure their safe return to earth.

needs to have many working parts lined up ready to be placed into the drilling sequence in the correct order and with a minimum time delay. The process is linear in nature with no flexibility to adapt the order of production and has only one method of achieving the prescribed goal. The process needs the right tools and personnel in the right place at the right time with little or no room for adaptation.

#### Table 2: Tight Coupling

| Delay in processing not possible  |  |  |  |  |  |
|---|--|--|--|--|--|
| Invariant sequences   |  |  |  |  |  |
| Only one method to achieve goal   |  |  |  |  |  |
| Little slack possible in supplies, equipment, personnel                 |  |  |  |  |  |
| Buffers and redundancies are designed-in deliberately                   |  |  |  |  |  |
| Substitutions of supplies, equipment, personnel limited and designed in |  |  |  |  |  |

It is therefore possible to assess systems to identify whether they are tightly coupled and complex. Fig 1 shows the interconnection of both parameters with coupling on the Y axis and interaction on the X. The top right of the graph depicts the tightly coupled and complex systems such as nuclear power plants and military aircraft. The graph is taken from Perrow's book and, following his logic, oil rigs have been added in the same position as chemical plants and aircraft carriers<sup>13</sup>. It would be reasonable to argue that due to the compact nature of oil rig design and the ambiguous nature<sup>14</sup> of oil drilling, oil wells could be positioned further along both the X and Y axis. The diagram illustrates that, due to similar complexity and coupling aspects of both military aviation and offshore drilling, it is possible to examine both processes through the same prism in order to compare operating processes. It

<sup>&</sup>lt;sup>13</sup> Ironically, the US oil and gas industry regard oil rig workers as "oil-field trash", as identified during interviews. Whereas those individuals employed on aircraft carriers are regarded as national heroes.

<sup>&</sup>lt;sup>14</sup> Oil deposits are a naturally occurring phenomenon and are therefore not of uniform pressure and size. Such variance adds complexity to any drilling venture.

is also worth noting that Perrow places Nuclear Plant in the top right corner. It would be logical to assert that floating nuclear reactors in combat ships could be considered to be even more complex.



# Figure 1: Interaction/Coupling Chart

Having established the similarities between closely coupled and complex organizations such as maritime aviation and the oil and gas industry it is important to examine the accepted thinking on accident theory and explore the concept of a safety culture.

#### Normal Accidents.

Normal Accident theorists believe that accidents are inevitable over time within organizations that involve complex and highly coupled technologies<sup>15</sup>.

"No matter how hard we try, no matter how much training, how many safety devices, planning redundancies buffers, alarms, bells and whistles we build into our systems, those that are complexly interactive will find an occasion where the unexpected interaction of two or more failures defeats the training, the planning, and the design of safety devices."<sup>16</sup>

Ultimately, theorists believe that there is nothing that can be put in place, be it automation or intrusive safety features that can mitigate the fragility of human interaction.

#### High Reliability Theory.

High reliable theorists are not as pessimistic as those that accept Normal Accident theory precepts and argue that highly complex systems can be designed to compensate for human failings. The more complex the technology the more intricate the organizational design and management techniques need to be. Weick and Sutcliffe in their book *Managing the Unexpected* examine how this theory would work within an organization and refer to the concept as a High Reliability Organization (HRO).<sup>17</sup> Fundamentally, Weick and Sutcliffe define an HRO as one that can suffer the impact of major incidents and recover quickly, and that *'these diverse organizations share a singular demand: They have no choice but to function reliably. If reliability is compromised, severe harm results'*.<sup>18</sup> As a result, actors within an HRO are attuned to spotting failure as they *'struggle to get it right on a continual basis'*<sup>19</sup> avoiding

<sup>18</sup> Ibid, p ix.

<sup>&</sup>lt;sup>15</sup> Scott D Sagan, *The Limits of Safety*, 1993, p28.

<sup>&</sup>lt;sup>16</sup> C Perrow, Cited by Scott D Sagan in *The Limits of safety*, 1993, p45.

<sup>&</sup>lt;sup>17</sup> Karl Weick and Kathleen Sutcliffe, Managing the Unexpected, 2007, (Jossey-Bass publishing).

<sup>&</sup>lt;sup>19</sup> Ibid, p xi.

complacency and arrogance towards their daily routine<sup>20</sup>. They tend to explore troublesome problems to see how they can improve any associated process and remain 'preoccupied with failure'. Weik and Sutcliffe propose that these principles can influence the system and move actors towards 'a state of 'mindfulness''.<sup>21</sup>

"Mindfulness is different from situational awareness in the sense that it involves the combination of ongoing scrutiny of existing expectations, continuous refinement, and differentiation of expectations based on newer experiences, willingness and capability to invent new expectations that make sense of unprecedented events. A more nuanced appreciation of context and ways to deal with it, and identification of new dimensions of context that improve foresight and current function".<sup>22</sup>

For the purposes of this paper one can accept that both theories have relevance in understanding risk and safety culture but one thing remains certain; the fallibility of the human form and psyche will continue to dog the best designs and the most stringent procedures. Human error will remain a fact of life, but it should be possible to design systems that are more resilient to any errors, be them mechanical or human. Resilience is therefore a realistic goal worth achieving and should sit centrally within any business plan.

<sup>&</sup>lt;sup>20</sup> Ibid, p xi.

<sup>&</sup>lt;sup>21</sup> Karl Weick and Kathleen Sutcliffe, *Managing the Unexpected*, p32.

<sup>&</sup>lt;sup>22</sup> Ibid

#### The concept of a Safety Culture

'Like a state of grace, a safety culture is something that is striven for but rarely attained. As in religion, the process is more important than the product. The virtue – and the reward – lies in the struggle rather than the outcome'<sup>23</sup>.

Professor James Reason explores the concept of a safety culture in his excellent book *Managing the Risk of Organizational Accidents*<sup>24</sup> and offers a succinct definition of that which he believes forms a Safety Culture. Professor Reason argues that a 'Safety Culture' can be 'engineered'; that its component parts can be nurtured to form the required whole. However this requires time and 'the persistent and successful application of practical and down-to-earth measures'<sup>25</sup>. Fundamentally, a safety culture is arrived at through sustained collective learning. The output of a team's approach, interaction and behavior is a safety culture that envelopes all organizational activities. Professor Reason captures this essence in the following definition:

"The safety culture of an organization is the product of individual and group values, attitudes, competencies, and patterns of behavior that determine the commitment to, and the style of, an organization's health and safety programs. Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventing measures"<sup>26</sup>.

Professor Reason then outlines the 7 key elements (pillars) that an organization needs to embrace in order to nurture an effective safety culture.

<sup>&</sup>lt;sup>23</sup> James Reason, *Managing the Risk of Organizational Accidents*, p220.

<sup>&</sup>lt;sup>24</sup> James Reason, *Managing the Risk of Organizational Accidents*.

<sup>&</sup>lt;sup>25</sup> Ibid, p192

<sup>&</sup>lt;sup>26</sup> Ibid, p194

The 7 pillars are:

- 1. An effective 'engine' that drives the culture towards a goal of maximum security.
- 2. Power of the engine is derived from not forgetting to be afraid complacency kills.
  - 3. Monitor the right data and embrace 'an informed culture'.
- 4. Engineer an effective '**reporting culture'**, to include errors and near misses.
- 5. Establish and maintain a 'just culture'.
- 6. Maintain the ability to reconfigure during high tempo ops or danger a 'flexible culture'.
- 7. An organization needs to maintain a <u>'learning culture'</u>.

Professor Reason then highlights four key ingredients (in bold) which make up an 'informed culture' which he proposes equates to a safety culture 'as it applies to the limitation of organizational accidents'<sup>27</sup>. The USN Nuclear endeavor clearly embraces the four key ingredients; it has an all-embracing reporting culture, it has a learning culture, is accepted as a just organization and continually demonstrates its flexible culture during combat operations. As one of the interviewees from within the USN Nuclear endeavor stated; '*Whenever confronted with an unknown or unplanned event you investigate – you apply this approach to any new business – you document any required actions and follow up*". Integral to the operational capability of the USN Nuclear endeavor is the understanding by all those involved that they are part of a 'just' team which, in itself, encourages an organization that is able to adapt during high tempo operations. As another interviewee from the USN nuclear endeavor stated; '*We do not need judgment in our system, we need to know why/how an accident happened and learn from it and move on. We adopted the Royal Navy's processes as an exemplar in this respect'.* 

<sup>&</sup>lt;sup>27</sup> Ibid, p196

Open reporting is highly encouraged and is a process that is mirrored in the military aviation domain where vigilance is both encouraged and rewarded.

# Importance of training within complex organizations

Professor Reason distills the main elements of an organization into 5 broad clusters, as listed below:<sup>28</sup>

- Safety-specific factors incident and accident reporting, safety policy, emergency procedures etc.
- Management factors management of change, leadership and administration, communication etc.
- Technical factors maintenance management, human-system interfaces, design etc.
- Procedural factors standards, rules, administrative controls, operating procedures etc.
- Training formal vs informal methods, presence of a training department, skills and competences to perform tasks etc.

He makes the assertion that 'at the core of these clusters and pervading all of them is the issue of culture', which 'exists within the organization as a whole, rather than in the mind of any senior manager'. The following diagram highlights this phenomenon where training is represented as a universal feature that binds the organization around a center core of 'leadership factors'. The whole organization is itself 'contained' within its own culture. Importantly, the character of the organization will be affected by the strength of the leadership and not the management contained therein. This is

<sup>&</sup>lt;sup>28</sup> James Reason, *Managing the Risk of Organizational Accidents*, p122.

especially important when dealing with highly complex and tightly coupled organizations that require clear leadership.



Figure 2: Main elements of an organization distilled into five broad clusters.

In 2005 the Health and Safety Executive in the UK published a review of safety culture and safety climate literature to distill a best practice document in order to help develop safety cultures within large organizations.<sup>29</sup> Relying heavily on Professor Reason's work the review provides a useful diagram that distinguishes between the three interrelated aspects of safety culture; psychological, behavioral and situational shown at figure 3. If the four key ingredients of the' informed culture' are 'married up' to the safety culture diagram it is possible to design an overarching model that can be used to assess a safety culture' have been transposed onto figure 3 in red. The positioning of the key ingredients is subjective and any of the 4 ingredients can obviously influence any of the three aspects of the safety culture, however an attempt has been made to combine the two concepts to form a useful working model. Underpinning the model is the concept of training as highlighted in figure 3.

<sup>&</sup>lt;sup>29</sup> A review of safety culture and safety climate literature for the development of the safety culture inspection toolkit, Human Engineering – HSE Books, 2005, Report 367. UK Crown.

Underpinning the 4 four key ingredients of a safety culture is an effective structure of legislation and it is here that the comparison between military and civilian organizations becomes more tenuous. Put simply, a military organization has to maintain operational capability whereas a civilian organization within the free market environment is driven by the need to make a profit. It is therefore clear to a military organization that the application of effective legislation will benefit the operational capability of that organization – passing the tests proves that the organization has demonstrated its operational capability. Operating unsafely can result in the loss of aircraft, which are expensive but can be replaced. More importantly the loss of an aircraft could result in the loss of crew members who are not so easily replaced. Therefore, an effective operational capability has to be a safe operation; the principle underpinning an 'operationalized' safety culture which is a concept that will be defined later in this chapter. During the Cold War all front line units, in order to conform to a state of readiness, were subjected to Tactical Evaluation (TACEVAL) teams, organized and legislated by NATO, who required all units to reach a prescribed level of operational effectiveness during both planned and surprise visits. A unit's effectiveness during such tests was regarded as either a badge of honor, or conversely, a badge of failure. This practice is still employed by Carrier Air Groups (CAGs) prior to embarking on an operational cruise and by the nuclear carrier crew itself. The professionalism of the personnel involved is rewarded by achieving the status of 'combat ready'. There is no additional monetary reward.

16



Figure 3 – The Essence of a Safety Culture. <sup>30</sup>

If operational capability is directly affected by the safety culture of a unit it is obvious that any unit wishing to pass rigorous operational tests and regulation will embrace a culture of safety; an effective

<sup>&</sup>lt;sup>30</sup> An adaptation of a diagram taken from Human Engineering – HSE Books, P4.

safety culture underpins a credible performance culture. In effect safety has been 'operationalized'; without a safety culture the military aviation community would be far less operationally capable. The pinnacle of this relationship is highlighted by the USN Nuclear endeavor. Operational capability of the USN nuclear powered capital ships has to be proven before they are deemed suitable to deliver combat air assets on the global stage. To be effective they first have to sail into international and national waters in order to conduct the full spectrum of international engagement and power projection, up to and including combat operations, for which they are designed. In order to sail unfettered into national waters the USN first has to prove that their Nuclear Carriers are safe to operate in or near other nations' coastlines; they are obliged to win trust by demonstrating absolute safety and it is in this aspect that the USN Nuclear endeavor has no peers. Even the civilian US nuclear power industry does not come close. Underpinning this is an absolute culture of safety which is 'ruthless' in its efficiency but allows the 7 pillars of a safety culture to thrive and can be regarded as the epitome of an 'operationalized' safety culture.

The USN has established and continues to maintain a healthy safety culture as depicted in figure 3 and has embraced to concept of 'operationalized' safety culture. By adopting an open reporting culture they are able to monitor compliance to procedures and establish trends in minor accidents. Fundamentally, the USN adheres to the principles of 'Heinrich's Triangle' depicted in figure 4. By monitoring the close calls or near misses in an organization, the theory states that an organization can take a pro-active approach to safety by focusing on the organizational processes and culture in an increasingly technological world by identifying potentially damaging trends<sup>31</sup>. Heinrich's Triangle is developed from the analysis of industrial accidents in the 1920s and depicts the relationship between

<sup>&</sup>lt;sup>31</sup> This approach eschews the concept of 'normalized deviation', a term credited to John Carlin, VP President Ginna Nuclear Plant. The concept reflects an acceptance of an organization to adopt procedural shortcuts until they become the 'norm'.

low-level deviations and major accidents. Professor J McDermid<sup>32</sup> asserts that 'good safety management identifies these low level issues and feeds them back to reduce risk'. The USN's adoption of an open reporting culture has enabled it to encourage the reporting of the lower order 'unsafe acts' and in so doing they are able to pro-actively mitigate against higher risk incidents developing. The USN nuclear endeavor takes this one step further by redefining the pinnacle event which, in the case of a nuclear powered ship is reactor meltdown. By redefining the pinnacle event, as depicted by the smaller triangle in figure 4, the USN has selected a more manageable pinnacle event which, if it were to occur, would not be catastrophic to operations, but would trigger a full safety review thus avoiding any catastrophic event from developing. This in essence is the concept that underpins an 'operationalized' safety culture.



Figure 4. Heinrich's Triangle adapted by the USN nuclear propulsion program

<sup>&</sup>lt;sup>32</sup> J A McDermid, PHD, *Through Life Safety Management: Some Concepts and Issues*, University of York, 2007.

#### CHAPTER TWO

"After being at Chernobyl, I drew the unequivocal conclusion that the accident was....the summit of all the incorrect running of the economy which had been going on in our country for many years."<sup>33</sup>

In order to analyze the strategic leadership within the Oil and Gas industry it will be necessary to distill what is required of strategic leaders of complex and tightly coupled organizations to sustain a safety culture. An examination of post-accident reports of major accidents suffered by similar organizations provides a rich seam from which to distill the core competences of a strategic leader. If the model at figure 3 is used as a structure against which to judge the effectiveness of strategic leadership one should be able to ascertain where strategic leadership has failed in past accidents. Having completed such analysis it should be possible to identify key failings that have occurred and, in so doing, distill the core competencies and then apply them to the current operational practices presently employed by the oil and gas industry and maritime military aviation practices. The five major accidents that will be used to form such a basis in this paper are: The loss of The Herald of Free Enterprise (1984); the Columbia Space Shuttle accident (2003); the RAF Nimrod XV230 aircraft explosion in Afghanistan (2006); the Piper Alpha oil rig disaster in the North Sea (1988) and the BP Texas City oil refinery explosion (2005). Each report will be examined in turn in order to distill the key elements of strategic failing in each accident. At first sight the five selected accidents may not appear to have much in common however they can be regarded as complex and coupled systems as depicted in figure 1.

<sup>&</sup>lt;sup>33</sup> Valery Legasov tapes, a transcript prepared by the US Department of Energy in 1988. Legasov was the First Deputy Director of Atomic Energy in the USSR at the time of the Chernobyl disaster and was a key actor within the government commission investigating the accident.

#### Columbia Space Shuttle

The most prominent of these accidents is the Columbia Space Shuttle with its very high degree of complexity and associated level of risk. The Haddon-Cave QC report into the loss of the RAF Nimrod MR2 Aircraft XV230 in Afghanistan in 2006<sup>34</sup> draws on the Space Shuttle disaster to identify failings in leadership that led to the mishap. With the various levels of organizational complexity within the oil and gas industry the Deepwater Horizon accident also has some uncanny similarities with the Columbia disaster which warrants particular attention especially as the Columbia Accident Investigation Board (CAIB) focused on the 'organizational causes' of the disaster.

"When causal chains are limited to technical flaws and individual failure, the ensuing responses aimed at preventing a similar event in the future are equally limited: they aim to fix the technical problem and replace or retrain the individual responsible. Such corrections lead to a misguided and potentially disastrous belief that the underlying problem has been solved. The Board did not want to make these errors. A central piece of our expanded cause model involves NASA as an organizational whole".<sup>35</sup>

The CAIB expressed that the organizational causes of the accident were fixed by the Organization's history and culture.

"Cultural traits and organizational practices detrimental to safety and reliability were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements/specifications); organizational barriers which prevented effective communication

 <sup>&</sup>lt;sup>34</sup> C Haddon-Cave QC, An independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 aircraft XV230 in Afghanistan in 2006, 2009, London: The Stationary Office.
 <sup>35</sup> CAIB Report, Chapter 7, p177.

of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements and the evolution of an informal chain of command and decision making processes that operated outside the organization's rules".<sup>36</sup>

The CAIB highlights the resilience of 'cultural norms' within an organization:

"Organizational culture refers to the basic values, norms, beliefs and practices that characterize the functioning of a particular institution. At the most basic level, organizational culture defines the assumptions that employees make as they carry out their work; it defines "the way we do things here". An organization's culture is a powerful force that persists through reorganizations and the departure of key personnel".<sup>37</sup>

The three CAIB excerpts were used in the Haddon-Cave report to highlight the organizational issues surrounding the Nimrod accident. This paper will draw on the three insights in order to examine the organizational culture, or character, of the oil and gas industry and how this character affects the development of a safety culture across all levels of the industry.

## BP Texas City Refinery

The accident at the BP Texas City Refinery on March 23, 2005, resulted, at that time, in one of the worst industrial disasters in U.S. history; *"Explosions and fires killed 15 people and injured another 180, alarmed the community, and resulted in financial losses exceeding \$1.5 billion.*<sup>38</sup> The report into the oil refinery explosion focused on the organizational causes of the accident and is explicit in identifying that

<sup>&</sup>lt;sup>36</sup> CAIB Report, Chapter 7, p178.

<sup>37</sup> Ibid p101

<sup>&</sup>lt;sup>38</sup> U.S. Chemical and Hazard Investigation Board, *Investigation Report BP Texas City* Report No.2005-04-I-TX, 2005 p17.

"[t]he Texas City disaster was caused by organizational and safety deficiencies at all levels of the BP Corporation."<sup>39</sup> The report highlights four key organizational causes of the explosion:

- *"BP Texas City lacked a reporting and learning culture. Reporting bad news was not encouraged, and often Texas City managers did not effectively investigate incidents or take appropriate corrective action.*
- BP Group lacked focus on controlling major hazard risk. BP management paid attention to, measured, and rewarded personal safety rather than process safety.
- BP Group and Texas City managers provided ineffective leadership and oversight. BP management did not implement adequate safety oversight, provide needed human and economic resources, or consistently model adherence to safety rules and procedures.
- BP Group and Texas City did not effectively evaluate the safety implications of major organizational, personnel and policy changes."<sup>40</sup>

# Herald of Free Enterprise

Although a car ferry is not an especially complex or closely coupled system, the accident of The Herald of Free Enterprise occurred during a manouevre whilst departing port that can be regarded as a complex operation with a high degree of coupling. The Herald of Free Enterprise, a cross-English channel car ferry, capsized in clear weather and calm seas on 6<sup>th</sup> March, 1987, outside Zeebrugge harbour in Belgium with the loss of 188 souls. The Formal Investigation was quite clear in its admonition of the leadership of the company operating the Herald of Free Enterprise:

"All concerned in management, from the members of the Board of Directors down to the junior superintendents, were guilty of fault in that all must be regarded as sharing responsibility for the

<sup>&</sup>lt;sup>39</sup> Ibid p18.

<sup>&</sup>lt;sup>40</sup> Ibid p179.

failure of management. From top to bottom the body corporate was infected with the disease of sloppiness.<sup>741</sup>

The investigation concluded with five points for future management of the ferry company:

- *"Clear and concise orders.*
- Strict discipline.
- Attention at all times to all matters affecting the safety of the ship and those on board.
   There must be no "cutting of corners".
- The maintenance of proper channels of communication between ship and shore for the receipt and dissemination of information.
- A clear and firm management and command structure."42

The investigation also passed comment on the regulations that governed the use of passenger ships. The assumption made when originally setting regulations was that *'if the hull was breached, the ship would remain afloat in a neatly upright condition for at least 30 mins'* which would allow the use of all lifeboats. However, with the evolution of Roll-On-Roll-Off ferries (as was the Herald of Free Enterprise) the investigation team concluded that *'there is a strong possibility that the ship will not remain upright for 30 mins'*<sup>43</sup>. The extension of an old set of assumptions to a new technology can also be seen in the DEEPWATER HORIZON accident, in which regulations established for the less challenging environment of shallow water drilling were applied without review to a more complex environment .

<sup>&</sup>lt;sup>41</sup> Department of Transport Formal Investigation into mv Herald of Free Enterprise, report of Court No. 8074, London, HM Stationary Office, 1987, p15.

<sup>&</sup>lt;sup>42</sup> Ibid p58.

<sup>&</sup>lt;sup>43</sup> Ibid p58.

#### Nimrod

The introduction of the Haddon Cave QC review into the loss of RAF Nimrod XV230 states that the aircraft *'was lost on 2 September 2006 whilst on a mission over Afghanistan when she suffered a catastrophic mid-air fire, leading to the total loss of the aircraft and the death of 14 service personnel on board*<sup>\*44</sup>. Although a catastrophic accident with the loss of 14 lives it did occur during combat operations and only involved one aircraft so why should this paper consider the accident when assessing strategic leadership failure? Firstly, the report is a very comprehensive safety review in its own right and offers an in depth investigation into cultural failings. Secondly, it offers an internal look into the failings of the very culture that this paper is using as a comparator to the oil and gas industry. This is important on several counts. In chapter one this paper explored the concept of HROs and Normal Accidents and concluded that, although advances will be made in technological design and organizational structure, human fallibility will always cast a shadow of doubt across all operations. Why then did this accident occur if the RAF is a so called HRO? Additionally, the method of investigation and recommendations outlined in the report can be regarded as indicators of the type of culture involved; the in-depth and thorough report can be regarded as the product of a just, learning and reporting culture.

The genesis of the Nimrod accident can be traced back to the 1960s when the original MR1 Nimrod design had a fuel cross-feed duct fitted during development from the De Havilland Comet. This was compounded in the late 1970s when the aircraft underwent modification to the MR2 standard and was fitted with Supplementary Air Conditioning (AC) Packs to cater for the additional electrical equipment fitted to the aircraft. The additional AC packs increased the potential for ignition. In the 1980s the Nimrod fleet of aircraft underwent further rapid modification to fit an air to air refueling capability in order to meet operational requirements in the Falklands War. These three modifications, although not linked, are an example of close coupling identified in chapter one and which had been in

<sup>&</sup>lt;sup>44</sup> Charles Haddon-Cave QC, *The Nimrod Review*, p9.

place for over half a century. As Weik and Sutcliffe point out, modern technical designs in conjunction with an effective organizational culture are required to mitigate the risks of dangerous operations; this was a very old aircraft design. So was the loss exclusively due to a series of old designs adopted before the concept of a safety culture had come into being? The answer is obviously no; the culture of the RAF had adapted to embrace evolving safety culture principles and today reflects much of the USN's approach to safety. An attempt to address the 'Safety Case' of the Nimrod fleet was undertaken in September 2002 but due to multiple reasons 'the Safety Case was a lamentable job from start to finish. It was riddled with errors. It missed the key dangers. Its production is a story of incompetence, complacency, and cynicism. The best opportunity to prevent the accident to XV230 was, tragically, *lost.*<sup>' 45</sup> The RAF had set out to address the safety of the Nimrod aircraft by applying contemporary processes but due to the impact of drastic savings measures introduced under the Strategic Defense Review the Service Support area had suffered fundamental reductions in manpower. This resulted in an unbalanced dependence on the commercial sector to provide the bulk of the work toward formulating the Safety Case, the process of which was undermined by a general malaise across the Nimrod organization; responsibility had been devolved to the private sector and after all, the aircraft had been flying safely for over 40 years. The loss of Nimrod XV230 was avoidable and an opportunity to address the coupling risks introduced with multiple modifications was squandered. 'Organizational causes adversely affected the ability of the Nimrod Integrated Project Team to do its job, the oversight to which it was subject, and the culture within which it operated, during the crucial years when the Nimrod Safety Case was being prepared.'<sup>46</sup> Haddon Cave QC concludes that 'organizational causes played a major part in the loss of XV 230' and goes onto make a raft of recommendations outlining that 'a safety culture that has allowed business to eclipse Airworthiness' as one of eight shortcomings in the current system.

<sup>&</sup>lt;sup>45</sup> Ibid, p10.

<sup>&</sup>lt;sup>46</sup> Ibid, p11.

#### Piper Alpha offshore platform

The Piper Alpha platform, an Occidental Petroleum owned rig operating in the British sector of the North Sea oil field suffered a catastrophic fire on 6<sup>th</sup> July 1988 with the loss of 165 lives from a crew of 226 and an additional 2 from a rescue ship. The sequence of events that quickly propagated and led to the disaster are a classic example of interaction within a closely coupled and complex system. A Post-Mortem analysis summarizes the chain of events thus: 'The accident chain started with a process disturbance followed by a pipe rupture that caused a vapor release. Several explosions followed and severed a petroleum line causing a pool fire. That fire impinged on a gas riser from another platform, which fueled an extremely intense fire under the deck of Piper Alpha'<sup>47</sup>. The investigation initially focused on the design of the platform as the reason for the tragic loss of life. The initial explosions and early stages of the fire had destroyed the control room, public address system, electrical power generation and a multitude of fire suppressing systems and 'the layout did not properly separate production modules from living quarters and command and control functions'<sup>48</sup>. Notwithstanding the obvious design flaws of Piper Alpha, the accident highlighted a deeper-rooted problem with the oil industry at the time. Due to management pressure, 'Piper Alpha was forced to a level of production of activity well in excess of the platform's original design criteria<sup>49</sup>. For example, at the time of the accident Piper Alpha was exposed to pressure levels of 625psi in a system that was designed for no more than 225psi; a decision driven by corporate management. The Public Enquiry into the accident led by Lord Cullen in 1990 highlighted further wide ranging failures in the oil industry as a whole, including the UK government authorities who, instead of adopting a pro-active level of regulation, were content to 'sit back' and adopt a hands off approach. The economic bonus to the UK economy from

<sup>&</sup>lt;sup>47</sup> M E Pate-Cornell, A Post-Mortem Analysis of the Piper-Alpha Accident, Stanford University, 1991, p1.

<sup>&</sup>lt;sup>48</sup> Ibid, p2.

<sup>&</sup>lt;sup>49</sup> Ibid, P2.

North Sea oil production in the 1980s was a very welcome fillip after the doldrums of the 1970s and therefore any regulation that stood in the way of oil-field exploitation was 'frowned upon'.

The production decisions to operate the system at a pressure level almost three times the designed safety level warrants further observation. Accident reports state that that *'the level of activity had been gradually increased without appropriate checking that the system retained an appropriate margin of safety'*<sup>50</sup>. How such a large pressure increase was accepted as 'safe practice' is hard to fathom, but the practice at the time was to gradually increase the operating pressure and, if the system did not fail, it was deemed to be a safe limit. (This activity was mirrored at the Texas City oil production accident commented upon earlier in the paper). It is especially pertinent to point out here that the decision to increase the pressure was not taken by those on Piper Alpha; it was taken at the corporate level. The Offshore Installation Manager could have requested a reduction in output pressure '*based on safety concerns, but the culture of the oil industry does not encourage this kind of request*'<sup>51</sup>.

Due to the multiple levels of operational, design and especially strategic leadership failings exposed by the Piper Alpha accident, the Lord Cullen report led the way for sweeping reforms in the UK oil industry and is used by many similarly complex organizations to benchmark<sup>52</sup> their processes. The key observation, however, is that many of the events that led to the loss of the Piper Alpha platform were *'clearly rooted in the culture, the structure, and the procedures of Occidental Petroleum and of the oil and gas industry in general*<sup>753</sup>. A combination of excessive production levels, low levels of personnel experience and associated training and a lack of understanding at the highest levels of production risks

<sup>&</sup>lt;sup>50</sup> Ibid, p29.

<sup>&</sup>lt;sup>51</sup> Ibid, p29.

<sup>&</sup>lt;sup>52</sup> Benchmarking will be discussed in chapter 3.

<sup>&</sup>lt;sup>53</sup> Ibid, p52.

all led to the Piper Alpha accident. Ultimately the desire to maximize profit prevailed over safety orientated decision-making and led to the death of 167 personnel.

## Strategic Leadership Failings

To sum up chapter two and set the conditions to examine the Deepwater Horizon accident the five preceding accidents share some or all of seven fundamental failings which have been provided at figure 5. The next chapter will examine the military aviation and nuclear domains to highlight how the inherent risks expressed in figure 5 have been mitigated within these inherently dangerous military operations. The chapter will also offer observations on how the military processes used to mitigate risks could have utility within the commercial sector.

|  | Columbia | Texas City | Free Enterprise | Nimrod | Piper Alpha |
|--|----------|------------|-----------------|--------|-------------|
| Inadequate Training/Learning Environment                             | х        | x          |                 |        | х           |
| Poor Risk Awareness  | Х        | X          | x               | Х      | Х           |
| Inadequate Regulations   |          | X          | x               | х      | Х           |
| Complacency at the Strategic level                                   | Х        | X          |                 | Х      | Х           |
| History of inadequate Organizational Safety Culture                  | х        | x          | x               |        | х           |
| Mistaking Tactical Safety Initiatives for Strategic Safety Awareness |          | X          |                 |        | Х           |
| Inadequate Regards towards Safety Procedures                         |          | X          |                 | Х      | Х           |

Figure 5. Seven Categories of Strategic Failure distilled from selected case studies.<sup>54</sup>

<sup>&</sup>lt;sup>54</sup> The crew who operated the Nimrod aircraft had an absolute regard for safety; unfortunately those responsible for formulating the safety case did not.

#### CHAPTER THREE

#### Military aviation

In 1952 the USN established the Naval Safety Centre (NSC) to advise the Chief of Naval Operations (CNO) as a means to manage aviation both afloat and ashore for the USN and USMC. At that time Naval Aviation was suffering 2066 Class A mishaps a year with a mishap rate of 54.03 per 100,000 flight hours<sup>55</sup>. According to data held at the NSC, the accident rate had dropped by 2008 to 22 a year with a mishap rate of 1.72. The graph at figure 6 highlights this dramatic improvement and reflects the USN's commitment to improving safety through an improved safety culture and associated processes. The accident rate in 1951 was clearly not sustainable and impacted the USN's operational capability through the attrition of aircraft and aircrew. The aircraft, although expensive, could be replaced from a pool of spare airframes which were purchased as part of an attritional buy; planners assumed aircraft would be lost and planned accordingly. The more taxing issue was the sustainment of the aircrew cadre which could not be so easily supplemented. Fast jet pilots take, on average, 4 years of intensive training to reach combat ready status and therefore any loss of experience through accidents would have an impact on the operational capability of a squadron. In 1951 it was therefore imperative that, as the USN embraced the jet age, it needed to embrace a more sustainable flying culture aboard its carriers.

<sup>&</sup>lt;sup>55</sup> Class A mishap: One in which the total cost of damage to property or aircraft exceeds \$1,000,000, or a naval aircraft is destroyed or missing, or any fatality or permanent total disability results from the direct involvement of naval aircraft. www.safetycenter.navy.mil.

The US School of Aviation Safety reflects this imperative through its mission statement;

'Enhancing mission readiness through the preservation of assets, both human and material'.



Figure 6. USN aviation accident rate since 1950<sup>56</sup>.

The USN initially engaged the University of Southern California to develop safety training within the aviation domain. Documents show that the initial approach relied on a retrospective view of incidents to identify existing problems. This was both expensive and highly reactionary however, considering the appalling safety record at the time, this should not come as a surprise. What this approach did allow is the adoption of innovative designs such as the angled deck and improved training programs. As figure 6 shows, the results were dramatic. Fundamentally, the USN had 'operationalized' safety to enhance its operational capability across all activities of flying; from training to war time operations, the USN had embraced safety as an operational enhancement. In order to understand the success of the above graph it is important to identify the key tenets behind the achievements.

<sup>&</sup>lt;sup>56</sup> Taken from Naval Safety Center publication, *The Hook*, winter 2008.

#### Leadership.

In 1951 the CNO, Adm Forrest Sherman, remained fully aware of the benefits of improved safety in naval aviation as he was himself a designated naval aviator with extensive and extraordinary experience in the world of carrier aviation. As the most senior officer of the USN at a time when the demands of a hot war in Korea and the intensifying Cold war in Europe were increasing pressures on his force, he fully understood the need for, and benefits of, a sustainable operational capability. This level of awareness is highlighted in Weik and Sutcliff's work<sup>57</sup> where they identify principles of a HRO<sup>58</sup> and propose that '*HRO*'s are sensitive to operations. They are attentive to the front line, where the real work gets done'.<sup>59</sup> The USN continues to employ naval aviators as Carrier Group Commanders and today's Commandant General of the USMC started his career as an FA18 fighter pilot. The USN leadership is therefore inculcated in the USN safety culture, across all levels of the executive, who have a thorough understanding of the benefits of an 'operationalized' safety culture (a concept introduced in chapter one) and support safety measures appreciating that by doing so they are enhancing the operational capability of the force they command.

#### Training.

The USN has embraced the concept of total training through a process known as NATOPS; Naval Air Training and Operating Procedures Standardization which is the USN's way of self-regulating. NATOPS pervades all aspects of a naval aviator's career, setting out the standards and training required of individuals at each step of their career ladder. In essence, NATOPS changed the old 'verbal pass-

<sup>&</sup>lt;sup>57</sup> Karl Weick and Kathleen Sutcliffe, *Managing the Unexpected*.

<sup>&</sup>lt;sup>58</sup> See p10.

<sup>&</sup>lt;sup>59</sup> Karl Weick and Kathleen Sutcliffe, *Managing the Unexpected* p12.

down' culture of naval aviation to one of a 'process and procedures' based culture. In the opening statement of OPNAV INSTRUCTION 3710.7U the CNO outlines the underlining principle of NATOPS:

'The NATOPS Program is a positive approach toward improving combat readiness and achieving a substantial reduction in the aircraft mishap rate. Standardization, based on professional knowledge and experience, provides the basis for development of sound operating procedures. The standardization program is not intended to stifle individual initiative, but rather to aid commanding officers in increasing their unit's combat potential without reducing command prestige or responsibility'. <sup>60</sup>

NATOPS is therefore the means through which the USN has 'operationalized' safety. To help explain the concept of 'operationalized' safety this paper will use a hypothetical 4-ship formation of attack aircraft operating from a deck of a USN Carrier tasked with a night Close Air Support (CAS) mission. The formation will be led by a crew member who has reached the NATOPS prescribed level of experience for such a task. His or her wingman will have reached his or her NATOPS level of competency as will the other members of the formation. The sortie will require a night launch, air to air refueling en route and CAS in support of foreign national troops in a hostile region affected by poor weather. Each step of the sortie has to conform to NATOPS prescribed standards; for example, has the crew had sufficient rest; have they conducted night air to air refueling recently; are they current in CAS procedures; are they current in the emergency simulator? The list of standards and experience is extensive and requires considerable effort to monitor. If the sortie is broken down into its constituent parts and analyzed, each phase can be regarded as highly complex with high levels of coupling. The risk of a serious mishap abounds across all phases of the sortie and it is through the development of NATOPS that the CNO can address those risks and mitigate them through training and experience, both of which

<sup>&</sup>lt;sup>60</sup> CNO cover note, OPNAV INSTRUCTION 3710.7U dated Nov 23 2009

are reflected in NATOPS. Naval Air operations are inherently dangerous but through the development of a safety culture, driven through publications such as NATOPS, the risk from the inherent dangers can be mitigated. This phenomenon can be regarded as the 'operationalizing' of safety and is dependent on a safety culture across all levels of the naval organization.

An example of an 'operationalized' safety culture can be demonstrated by the concept of crew rest. Flying complex fighter aircraft requires a clear and rested head and therefore adequate crew rest is an absolute requirement for anyone programmed to fly. This is often a challenge when one considers the dynamic environment of a USN Aircraft Carrier, yet squadrons take great efforts to ensure that their aircrews are sufficiently rested before embarking on any flying duties. The rest requirements are laid out in NATOPS and rest times are monitored closely to ensure all aircrew comply. The crew of the hypothetical 4-ship formation would have rested sufficiently prior to planning their sortie although their natural circadian cycles would have been affected by flying at night. This additional risk of flying at night is mitigated by experience; crews will gain their day combat ready status well in advance of their night combat ready status. Again, this is laid out within NATOPS.

The complexity of flying combat sorties is dependent upon thorough planning as well as comprehensive briefing. The briefing confirms that all actors within the formation have a clear understanding of that which is required of them during the sortie as some members may have missed aspects of the plan during the planning process itself. During the briefing process, emergency procedures pertinent to the sortie will be discussed as well as forecast weather conditions and attack procedures. In the case of Close Air Support, the accurate completion of attack procedures is especially relevant to the troops on the ground as any inaccurate weapon programming could end with the delivery of ordnance onto the very troops the formation was sent to assist. This is an example of the importance of an 'operationalized' safety culture. The ability to safely drop ordnance in any weather or

34

at any time of day to impact within 500 feet from friendly forces, in order provide lifesaving assistance appears incredibly hazardous yet the inherent dangers have been mitigated through the application of an 'operationalized' safety culture.

The examination of the hypothetical 4-ship formation example has only 'scraped the surface' of the various aspects of the USN flying organization but it clearly demonstrates how the USN has embraced a safety culture, through NATOPS and training, that addresses the primary process subsystems underlying organizational safety as depicted in figure 3. The key to the success of NATOPS has been the inculcation of the need to continually train, monitor and to some degree, test all actors involved in the flying operation. With training, comes experience, which is monitored; aircrew are obliged to keep updated personal files, or NATOPS jackets, that fully outline the level of experience and proficiency that they have reached in their training. The standards are centrally set and are frequently inspected to ensure that all operational squadrons are compliant with the NATOPS standards. This process is time consuming and expensive but the result is a fighting force that can be monitored for combat effectiveness and is able to operate safely across all aspects of combat aviation.

#### USN Nuclear Endeavour

During several interviews conducted for this paper, employees at the management level of the oil and gas industry referred to the concept of benchmarking which is the process of comparing practices in one organization with those of a recognized leader in a comparative field and then implementing any noted better practices. The concept of benchmarking takes two forms; informal and formal. Informal benchmarking is a process that we undertake upon a daily basis, be it through consulting experts, networking or on-line research. Formal benchmarking can be broken into two further subsets; performance and best practice benchmarking, both of which require a focused study. During interviews conducted for this paper the question of benchmarking was raised and was met with a

35

mixed response. Specifically, the US nuclear industry and USN nuclear endeavor, discussed in chapter one, were both cited as 'benchmarks' that were used to provide best practice guidelines. However, it was not clear how the benchmarking process was conducted. If there was a formal process it was not evident from the interviews. However, the 'benchmark references' that were cited warranted further analysis as the observations inadvertently chimed with the thesis of this paper.

The USN nuclear endeavor has a remarkably impressive safety record<sup>61</sup>, but the 'human' resource, in both time and effort that is applied to achieving this record should also be regarded as 'remarkable'. Adm H G Rickover's legacy of zero reactor accidents<sup>62</sup> over the history of the USN nuclear endeavor is the result of an 'extreme' safety regime which this paper argues would be untenable in any civilian environment. The phrase 'extreme' is relative, as the USN safety regime is regarded, internally, as an essential part of the USN day to day operations and without it, the USN legacy of zero reactor accidents would probably be a shattered aspiration. Adm Rickover's own words express his approach to developing a safety culture within the USN:

"Over the years, many people have asked me how I run the Naval Reactors Program, so that they might find some benefit for their own work. I am always chagrined at the tendency of people to expect that I have a simple, easy gimmick that makes my program function. Any successful program functions as an integrated whole of many factors. Trying to select one aspect as the key one will not work. Each element depends on all the others."<sup>63</sup>

<sup>&</sup>lt;sup>61</sup> 'As at the end of 2011 the USN were operating 84 nuclear-operated vessels – since 1962, no civilian or military personnel in the Navy Nuclear Propulsion Program have ever received more than a tenth of the Federal annual occupational exposure limit'. Occupational Radiation Exposure report NT-12-2, May 2012, p1.

<sup>&</sup>lt;sup>62</sup> The uncontrolled release of fission products to the environment resulting from damage to a reactor core.

<sup>&</sup>lt;sup>63</sup> Taken from Admiral Rickover's testimony before Congress post Three Mile Island accident, 1979.

From this concept the USN nuclear safety principles were clearly defined as described by Adm Bowman, Director, Naval Nuclear Propulsion Program:

"Safety is the responsibility of everyone at every level in the organization. Safety is embedded across all organizations in the Program, from equipment suppliers, contractors, laboratories, shipyards, training facilities and the Fleet to our Headquarters. Put another way, safety is mainstreamed. It is not a responsibility unique to a segregated safety department that then attempts to impose its oversight on the rest of the organization." <sup>64</sup>

Admirals Rickover and Bowman make very clear observations of what it takes for an organization to achieve a functioning safety culture and one would surmise that this is within reach of most organizations. However, the complexity of the USN nuclear endeavor cannot be trivialized as the resultant 'fallout' if anything were to go seriously wrong dictates that the safety culture needs to be 'ruthless' in its application. All incidents are investigated, all unexpected outcomes<sup>65</sup> are scrutinized to understand how they evolved and 'all hands' are trained to be part of the safety culture. The USN operates a 'flat reporting' system whereby key executives and safety 'experts' report directly to the Director, Naval Nuclear Propulsion Program, on a weekly basis – and the Admiral personally reads 'every report, every time'. '*Safety is the responsibility of everyone at every level in the organization*'<sup>66</sup> including the Director, but his 'inclusion' requires firm regulation and time consuming processes. This paper believes that the USN nuclear level of 'absolute safety' is unachievable within the financial constraints of the Oil and Gas industry, but aspects of the process remain applicable. The industry can therefore

<sup>&</sup>lt;sup>64</sup> Taken from Admiral F Bowman's statement before the House of Committee on Science, 29 Oct 2003.

 <sup>&</sup>lt;sup>65</sup> An 'unexpected outcome' is a more collective phrase for 'incident' in order to capture all anomalies within the nuclear process. This reflects the 'absolute safety' policy that is employed within the USN nuclear community.
 <sup>66</sup> Ibid

'benchmark' from key components of the safety process which are reflected in the dynamic environment of military aviation – a complex environment but with less 'fall out' if things go wrong.

#### Military Aviation as a Benchmark

To analyze the vital ingredients of the military aviation safety culture one needs to refer back to figure 3 in chapter one where this paper proposed a model depicting 'the Essence of a Safety Culture'. The diagram outlines the psychological, behavioral and situational 'Aspects' executed within the day to day routine of a USN Carrier at sea or a front line combat squadron deployed on operations. The execution of the example four-ship sortie needs to meet all three 'aspects' if it is to complete its sortie safely and effectively. In order to achieve this, the squadron needs to operate within a just, learning, reporting and flexible culture all of which is tied together within a training environment. This can only be achieved if a safety culture is in effect which, in turn, can only exist if it is nurtured by the strategic leadership of the organization that embraces the concept of 'operationalized safety'.

Having proposed a model to define 'the Essence of a Safety Culture' in figure 3, this paper used the model to explore the safety culture within the USN military aviation and nuclear domains. This gave rise to the concept of an 'operationalized' safety culture which ran through all levels of operation. The next chapter will now examine the Deepwater Horizon accident using the same criteria.

38

#### **CHAPTER FOUR**

#### The Deepwater Horizon Accident

'The Deepwater Horizon accident could have happened to any one of the oil companies drilling in those deep waters'<sup>67</sup>.

The Deepwater Horizon accident occurred during exploratory drilling on the Macondo well which sits 13,000 feet below the sea floor which is itself under 5000 feet of water. The engineering challenges facing the drilling teams exploring deep water deposits are considerable; 'the remarkable advances that have propelled the move to deep water drilling merit comparison with exploring outer space'68. The desire to exploit hydrocarbons from increasingly more challenging locations is driven by the high demand for petroleum based products. In the United States, oil exploration and exploitation relies on private industry whereas in other countries the oil industry is either wholly or partly owned by the State and is therefore, on the most part, more tightly regulated. In the US, the free market economy, through the private-enterprise system encourages and rewards hydrocarbon extraction financially. The US receives considerable revenue from the selling of mineral rights making it the second biggest earner for the country after IRS returns. But the free market ideology that underpins the oil and gas industry 'has major implications for how the US government oversees and regulates offshore drilling'.<sup>69</sup> The industry remains highly innovative, quickly developing drilling techniques to overcome deep water challenges, but it is also vigorously competitive, driven by the need to make a profit. The free market pressures therefore drive exploration through the application of new technologies where the risks facing the venture may not have been fully addressed. The Deepwater Horizon, it could be argued, was such a

<sup>&</sup>lt;sup>67</sup> Interviewee, manager of Gulf of Mexico rig.

 <sup>&</sup>lt;sup>68</sup> 'Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling', Report to the President, National Commission on the BP DWH Oil Spill, January 2011, p viii.
 <sup>69</sup> Ibid, p viii.

venture, operating at the edge of the 'envelope' when drilling at such depths in the Gulf of Mexico. The rig was highly complex with many closely coupled systems; it was operating in an environment that is 'cold, dark, distant, and under high pressure – and the oil and gas reservoirs, when found, exist at even higher pressures, compounding the risks if a well gets out of control<sup>70</sup>. The depth of the operation therefore makes the drilling sequence extremely challenging but additionally, any malfunction or incident will be harder to diagnose and then control, and any activities to regain control of a failure will be compounded by the extreme depth. Government oversight failed to keep up with the new drilling environment with its compounded risk. 'Investments in safety, containment, and response equipment and practices failed to keep pace with the rapid move into deep water drilling'<sup>71</sup>. Figure 7 clearly shows the rate of growth of deep water exploitation in the Gulf of Mexico which increased dramatically in the late 1990s. The three challenges of how to drill; how to keep control of drilling operations and how to regain control if lost in extreme conditions did not gain the same levels of attention by the drilling companies. The Deepwater Horizon report clearly exposes the BP desire to drill using regulations not designed for deep water exploration but with limited thought to how they would cope with any loss of control. Interviews of individuals from other companies also highlighted a similar disparity in focus. The oil companies were striving to match demand with supply and this financially driven process shaped their drilling behavior which inadequate government legislation failed to monitor.

<sup>&</sup>lt;sup>70</sup> Ibid, p ix.

<sup>&</sup>lt;sup>71</sup> Ibid, p ix.



Figure 7. MMS Offshore budget and GOM Oil Production 1984-2009.<sup>72</sup>.

Having set the financial context, the paper will now explore the Deepwater Horizon accident against the seven fundamental failings identified in figure 5.

#### Inadequate Training/Learning environment

From the numerous interviews conducted it quickly became apparent that there is no accepted standardized training requirement within the oil and gas industry. Rig workers are expected to 'pick up' the job as they go along; a working apprenticeship if you will. The accident report underlined this issue with the following statement: *'The rig crew had not been trained adequately how to respond to such an emergency situation. In the future, well-control training should include simulations and drills for such emergencies – including the momentous decision to engage the blind shear rams or trigger the Emergency Disconnect System.'<sup>73 74</sup> The fact that the crew had not considered emergency procedures* 

<sup>&</sup>lt;sup>72</sup> Graph taken from National Commission on the BP Deepwater Horizon Oil Spill Staff Working Paper no. 21

 <sup>&</sup>lt;sup>73</sup> The EDS and blind shear rams should sever the drill pipe, seal the well, and disconnect the rig from the oil pipe.
 <sup>74</sup> Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling, Report to the President, National Commission on the BP DWH Oil Spill, p122.

prior to conducting such a dangerous manouevre is an anathema to anyone that has served on a military ship. Compounding this problem is the 'complex' relationship between the drilling manager, who is employed by the operator and the rig crew who are employed by the contractor. How the manager is able to influence the rig crew will have a direct impact on the effectiveness of the Safety culture experienced on the rig. The adage that, whilst afloat, everyone is a 'sailor first' is something that the Royal Navy and USN reinforce to all who serve on board. This includes pilots who are required to undertake the same battle-damage control training as all of the other ship crew; a sinking ship does not differentiate between individuals' level of operational capability.

In addition to poor training on the rigs, the Mineral Management Service (MMS now BOEM and BSEE<sup>75</sup>) regulators also remained inadequately trained; *'ultimately, MMS was unable to ensure that its staffing capabilities and competencies kept pace with the changing risks and volume of offshore activity'* and *'MMS frequently lacked defined qualifications that new employees must meet before they start performing their jobs'*<sup>76</sup>.

The learning environment is not reflected in the commission report and it is therefore difficult to pass comment. However, the participants at the 3<sup>rd</sup> International Regulators' Offshore Safety Conference in October 2010 noted that: '*Regulations should serve as catalysts for learning by distributing information, hosting workshops, participating in research, and identifying gaps in standards and best practices....Sustaining outstanding performance is critical to the reputation of industry and government*'.<sup>77</sup> This observation came in the wake of two of the industry's worst offshore blowouts in history and suggests that a learning environment is lacking across the industry. This observation on its

<sup>&</sup>lt;sup>75</sup> Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) 1 Oct 2011.

<sup>&</sup>lt;sup>76</sup> Ibid, p79.

<sup>&</sup>lt;sup>77</sup> 'Conference Summary', International Regulators' Forum,

http://www.irconference2010.com/showcontent.aspx?MenuID=940.

own may be harsh but a comment by an interviewed senior drilling manager reinforced the need for an improved learning environment on oil rigs: "What's missing is leadership training – roughnecks are promoted because they understand the technical aspects of the job but they have no people skills – they need to be taught how to lead. Over the last 20 years the complexity of the job has increased substantially and therefore the leadership challenges have increased".

This may be a result of the 'on-the-job training' process that is the accepted training format on oil rigs. Such a process encourages a 'hands on' approach to operations but, arguably, often avoids addressing leadership principles surrounding engineering procedures.

#### **Inadequate Regulations**

"The industry needs a robust, expertly staffed, and well-funded regulator that can keep pace with and augment industry's technical expertise. A competent and nimble regulator will be able to establish and enforce the rules of the road to assure safety without stifling innovation and commercial success"<sup>78</sup>.

The regulations set for the US oil and gas industry at the time of the Deepwater Horizon accident were inadequate. The National Commission on the BP Deepwater Horizon oil spill is quite clear in this observation. The graph at figure 7 not only indicates the rapid growth in deep water drilling it also highlights the inadequate government investment in the MMS. The MMS was formed in 1981 under then Interior Secretary James Watt in the Reagan administration and was charged with both the collection of revenue generated by selling drilling permits as well as approving the permits in the first place. MMS were therefore torn between the regulation, and collection of revenue, from the same

<sup>&</sup>lt;sup>78</sup> Testimony of Marvin Odum, President, Shell Oil Company, and Upstream Americas Director, Royal Dutch Shell, 9 November 2010.

companies<sup>79</sup>. Any rejected permit would result in a drop in revenue. However, singling out the MMS for criticism for failing to keep abreast of deep water drilling is unfair. In 1998, the MMS attempted to address the challenges of deep water drilling by implementing a 'performance management approach' in deep water wells. In effect the MMS were moving towards a 'regulatory regime tied more to performance and less to prescription'<sup>80</sup> similar to the effective regimes experienced in the North Sea oil fields. However, the increased burden of reviewing the complex technical drilling assessments stressed the limited resources of the MMS who were compelled to announce an increase in the rental rates on deep water leases in order to supplement the agency's growing oversight responsibilities. Industry responded by successfully lobbying the Gulf Coast Congressional delegates so that the initiative to collect the required extra funding was overturned. The MMS attempted to introduce several other initiatives including a more comprehensive incident reporting system and voluntary reporting of performance measures<sup>81</sup>. Both measures were eventually overturned by the White House Office of Management and Budget. The MMS were therefore fundamentally undermined by industry and inadequately supported by government. Nineteen days after the Deepwater Horizon accident, Secretary of the Interior Ken Salazar announced that he would divide the responsibilities of the MMS into two thus removing the conflicting interest within the government's own regulatory body. The National Commission investigating the accident concluded that 'the rig's demise signals the conflicting evolution- and severe shortcomings-of federal regulation of offshore oil drilling in the United States, and particularly of MMS oversight of deep water drilling in the Gulf of Mexico'82.

<sup>&</sup>lt;sup>79</sup> In March 2008, BP paid @\$34 million to the MMS for a lease to drill in Mississippi Canyon Block 252 which included the Macondo well.

 <sup>&</sup>lt;sup>80</sup> National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, Staff Working Paper No.21, p4.
 <sup>81</sup> Ibid, p6 footnote 16.

<sup>&</sup>lt;sup>82</sup> Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling, Report to the President, National Commission on the BP DWH Oil Spill, p55.

The failure of the government to provide adequate regulation no doubt played a fundamental part in the loss of the Deepwater Horizon rig, and the fact that adequate regulation was not in place should not assuage the responsibility of the drilling companies. The very name of the drilling platform summed up the task in hand; the company was drilling in deep water and expanding its engineering horizons to adapt to the challenges inherent in the process. The risks involved in such an operation are considerable so why rely upon, much less undermine, attempts by the government regulators to provide the safety framework? In the first place, regulators were held in low regard by the oil workers. In the words of one oil worker, "The Government inspectors are on postal worker pay<sup>83</sup>. We know the surprise inspection is coming as we need the fuel available on the rig for the incoming helicopter, and when they arrive they go straight to the galley. They then check books for admin compliance – check all loose parts are labeled (in case they float from the rig and wash up on shore) and focus on the little stuff<sup>v84</sup>. The National Commission makes the following observation about the MMS; "the MMS personnel responsible for reviewing the permit applications submitted to MMS for the Macondo well were neither required nor prepared to evaluate the aspects of that drilling operation that were in fact critical to ensuring well safety".<sup>85</sup> If the companies had embraced a concept of operationalized safety all those involved with the drilling process would have provided a level of self-regulation as they pushed the boundaries of exploration; the company, at all levels, would have demanded it.

#### Inadequate regard to Safety procedures

Once oil had been discovered, the Deepwater Horizon exploratory rig would need to seal the well as it had completed its part of the process. However, the added pressure from drilling at such a

<sup>&</sup>lt;sup>83</sup> The Commission report makes the observation that 'MMS engineer salaries were stuck in the midranges of the federal pay scale, and were far too low to attract individuals possessing the experience and expertise needed to oversee the increasingly complicated oil and gas drilling activities in the deep water of the Gulf.'
<sup>84</sup> Interviewee Dec 2012, senior rig worker with over 25 years' experience.

<sup>&</sup>lt;sup>85</sup> *Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling*, Report to the President, National Commission on the BP DWH Oil Spill, p77.

depth would complicate the sealing procedure with an increased risk of a volatile 'blowout<sup>86</sup>'. To identify the entry of hydrocarbons into the riser pipe, an event known as a 'kick', during the early stages of a blowout, the well-head engineers are required to carefully monitor the process. In the event of a 'kick', they are required to initiate various procedures which, in the worst case, would result in the blowout preventer valve mechanically closing the riser pipe. Such a manouevre is regarded as a last ditch action as it takes considerable time, and therefore money, to remove once set in place. In the case of the Deepwater Horizon the company exacerbated the risk of a blowout by making nine time-saving decisions as indicated in figure 8. With such an increased threat of a blow-out one would imagine that the crew would discuss blowout safety procedure drills, recap on indications of a kick in progress, identifying who would make the call to activate that blowout preventer and possible practice a blowout preventer initiation procedure. None of these appear to have been completed and, from conducted interviews, it does not appear to be standard practice within the oil and gas industry as a whole.

#### History of Inadequate Organizational safety culture

Two of the accidents identified in chapter two are both associated with the oil and gas industry<sup>87</sup>. Many of the observations made in those reports are again reflected in the Deepwater Horizon accident report. One could argue, therefore, that there is a history of an enduring organizational failure to foster a safety culture within the oil and gas industry. Although this may be mainly true, it would be unfair to dismiss the investment that the industry has made into trying to improve its safety standards. Advances have been made and the statistics of personal injuries show that the US oil and gas drilling environment has become safer. But this paper posits that the bulk of the effort has made a direct impact at the tactical level while ignoring the strategic level. A quote from an

<sup>&</sup>lt;sup>86</sup> Highly flammable hydrocarbons exit the well head in an uncontrolled manner.

<sup>&</sup>lt;sup>87</sup> Texas City oil refinery and Piper Alpha

interviewed tool-pusher with 23 years' experience makes the point: "In today's offshore environment everyone is so focused on brain washing the work force in safety jargon and bombarding them with safety awareness posters and pocket paraphernalia, they are now starting to resent it". Another driving factor to improve safety at the tactical level appears to be the litigious nature of today's society. Injuries sustained on an oil rig, where inadequate levels of tactical safety have been addressed often result in law suits against the owner. Another interviewee stated that 'at one time in my career every worker on one oil rig was pursuing litigation against the company for a personal injury claim'. Although this was only one observation it does beg the question, why are oil companies so focused on sorting out the tactical level of safety? Is it to introduce a total safety culture or is it to drive down costs incurred by personal injury and the resultant delay in drilling? The interview process was unable to reach a conclusion on this question, but the more fundamental question remains; what safety practices have been adopted at the strategic level?

#### Mistaking tactical safety initiatives for strategic safety awareness

The Deepwater Horizon rig had a commendable regard for safety procedures at the time of the accident. Ironically, when the accident occurred, the rig had been due to receive an award for safe operations<sup>88</sup>. However, this paper contends that the level of safety achieved by the oil rig workers on the Deepwater Horizon was at the 'tactical' safety level. At the 'strategic' level, the accident report finds that the operator<sup>89</sup> compounded the risks towards the rig's integrity through a series of time and money-saving decisions made by the shore based operations team. In addition, there is no evidence that any of the involved companies' personnel who decided on the time saving measures actually conducted any form of risk analysis. Figure 8 outlines nine key decisions that, made in isolation, should

<sup>&</sup>lt;sup>88</sup> MMS issued its SAFE award to Transocean for its performance in 2008, crediting the company's 'outstanding performance' and a 'perfect performance period'.

<sup>&</sup>lt;sup>89</sup> The operator is the main oil company owning the rights to explore an oil field.

have been considered risky within the new deep water domain in which the rig was operating. The fact that no consideration was given to the added risk of taking these decisions is a clear indicator of an organization with limited strategic safety awareness. This paper will not explain each decision in detail, suffice it to say that official reports into the accident have identified each decision, in isolation, as a stepped increase in risk. The fact that employees working on the rig, in addition to those running the operation from land, appeared not to consider the cumulative risk of their decisions, whilst undertaking drilling operations in such a challenging environment, clearly indicates a failure of the awareness of safety as a strategic necessity. This is not an example of an operationalized safety culture.

| Decision  | Was There A Less Risky<br>Alternative Available? | Less Time Than<br>Alternative? | Decision-maker                              |
|---|--|--------------------------------|---|
| Not Waiting for More<br>Centralizers of Preferred Design  | Yes  | Saved Time                     | BP on Shore                                 |
| Not Waiting for Foam Stability Test<br>Results and/or<br>Redesigning Slurry   | Yes  | Saved Time                     | Halliburton<br>(and Perhaps BP)<br>on Shore |
| Not Running Cement<br>Evaluation Log  | Yes  | SavedTime                      | BP on Shore                                 |
| Using Spacer Made from<br>Combined Lost Circulation<br>Materials to Avoid Disposal Issues   | Yes  | SavedTime                      | BP on Shore                                 |
| Displacing Mud from Riser Before<br>Setting Surface Cement Plug   | Yes  | Unclear                        | BP on Shore                                 |
| Setting Surface Cement Plug 3,000<br>Feet Below Mud Line in Seawater  | Yes  | Unclear                        | BP on Shore<br>(Approved by MMS)            |
| Not Installing Additional<br>Physical Barriers During Temporary<br>Abandonment Procedure  | Yes  | SavedTime                      | BP on Shore                                 |
| Not Performing Further Well Integ-<br>rity Diagnostics in Light of Troubling<br>and Unexplained Negative Pressure<br>Test Results | Yes  | Saved Time                     | BP (and Perhaps<br>Transocean) on Rig       |
| Bypassing Pits and<br>Conducting Other<br>Simultaneous Operations<br>During Displacement  | Yes  | SavedTime                      | Transocean<br>(and Perhaps BP)<br>on Rig    |

Figure 8. Examples of time saving decisions that increased risk at the Macondo well. <sup>90</sup>

<sup>&</sup>lt;sup>90</sup> Graph taken from: *Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling*, Report to the President, National Commission on the BP DWH Oil Spill, p125.

However, a perplexing aspect of this paper has been trying to rationalize why a rig that had just won an award for safety procedures in the Gulf could suffer such a catastrophe. Surely, by applying Heinrich's triangle theory, the Deepwater Horizon safety record indicated such an accident was highly unlikely? Based on what was learned in interviews, this paper posits that the safety team, through their application of the principles of Heinrich's triangle, had unwittingly masked any true operational risk; the triangle appeared fractured. The strategic leadership had divested responsibility for safety to a team of safety experts who focused their efforts on operations at the tactical level. In effect this was not strategic leadership but a demonstration of management principles and led to the isolation of the strategic level from the safety concerns at the tactical level. The safety team 'sat within the fracture' concentrating their initiatives downward and unwittingly driving a wedge into the organizational structure. The workers at the tactical level, strongly encouraged to achieve high levels of personal safety, found themselves inundated with various safety initiatives. As one interviewee observed, "we were obliged to offer a safety related observation on a daily basis. We just took a handful of safety forms home to our wives on our down time and asked them to get imaginative with the forms and we would then offer them up, one a day, on our return to the rig".

Compounding the phenomenon of a fractured organization was the desire of many workers to remain employed on the rig, instead of accepting a shore based position, as the pay and time-off were both considered as key benefits of the rig based job. This appeared to be an in-grained cultural issue. When it came time to promote individuals into shore based operational posts it appeared from interviews that many did not want to give up their rig orientated life style. Promotion to a shore based job, although slightly better remunerated, came with extended working weeks and no 'down-time'. It also involved a considerable increase in paper work which was a responsibility that was not embraced

49

by the average rig hand<sup>91</sup>. As a result the senior experienced rig hands choose to remain on the rig allowing more junior and possibly less capable workers to take up the shore based operational posts. The result of such a practice is the development of a tactical portion of the Heinrich triangle which becomes self-perpetuating with insufficient breakthrough to the next level of command. The strategic portion of the triangle that sits above the safety team also adds to the fractured phenomenon. Driven by the need to increase profits and content to divest safety responsibility to the safety team, they appear to accept the safety statistics advertised on a regular basis as an indicator of overall safety. The Deepwater Horizon event is a perfect example of this phenomenon; if the industry was truly driven by safety how could they choose to drill with so many compounding risks, with an insufficient safety case and outdated regulation? The Heinrich approach to safety certainly works in the US Navy as they have 'operationalized' safety. However, this paper believes the theory is not being correctly applied within the oil and gas industry. The fracture within the triangle is not obvious to the safety-team as they are able to demonstrate tactical success. The tactical level are content to stay within their 'work zone', actively avoiding promotion and the strategic level is happy with the regularly produced safety-team reports satisfied, from a management perspective, that the principles behind the Heinrich triangle approach must be working.

#### Complacency at the Strategic Level

In the case of the Deepwater Horizon accident, the strategic level can be regarded as both government oversight and company leadership. This section has already outlined how the regulators failed to keep abreast of deep water drilling practices and how company management mistook tactical safety initiatives as an effective strategic safety culture. Both these failings can be linked to a complacency that affected both the MMS and the upper echelons of the oil and gas industry leadership.

<sup>&</sup>lt;sup>91</sup> Many rig hands leave school at the earliest opportunity and may only have a very basic high school education. This is probably a key factor in forming the working culture on board an oil rig.

In the case of the MMS, as long as they were drawing in the leasing funds, there was a general acceptance that they were achieving their aims (see footnote 96). In the case of the management, as long as they were complying with the regulations, all would be well: 'Congressional investigation revealed that the response plans submitted to MMS by ExxonMobil, Chevron, ConocoPhillips, and Shell were almost identical to BP's – they too suggested impressive but unrealistic response capacity'<sup>92</sup>. It would appear from the report that complacency was an issue across the industry. This appearance was also reflected in interviews. There is also evidence garnered from interviews that all blow out preventer valves in the GOM in the wake of the Deepwater Horizon accident were assessed and found to have at least one defective mode of operation. Each Blow Out valve has several systems designed to be mutually supportive; a failure in one mode should be backed up by several other modes. However, through interviews it became apparent that industry executives were content to use the valves as long as they had some systems operational; "Some have multiple failures and still industry uses them as there is a belief within the industry that as long as one or more methods are operational then the system is serviceable"93. The Blow Out preventer recovered from the wreck of the Deepwater Horizon when examined 'had a faulty solenoid in the yellow pod and low charge batteries in the blue pod. The investigation team has determined that these conditions very likely prevailed at the time of the accident. If so, neither pod was capable of completing an AMF' (Automatic Mode Function).<sup>94</sup> When the Deepwater Horizon wellbore 'blew' the blow out valve failed to harness the Macondo well; 'It is possible that the first explosion had already damaged the cables' when the main emergency disconnect system was initiated. It is important to note that the complacency at the Government level was borne out of an incorrect assessment of the risks at play; no one in Government had grasped the potential impact or magnitude of a deep water blowout and had assumed that there was capacity to deal with such an

<sup>&</sup>lt;sup>92</sup> Ibid, p133.

<sup>&</sup>lt;sup>93</sup> Interview with senior member of the Department of the Interior.

<sup>&</sup>lt;sup>94</sup> BP Deepwater Horizon Accident Investigation Report, 8 Sep 2010, p152

event.<sup>95</sup> This was partly due to the convincing message coming from the oil and gas industry which reassured the regulators that technology had adapted to overcome the increased challenges of deep water drilling.

# Poor Risk Awareness

With a level of complacency at the strategic level, driven in part by the misconception that the tactical safety initiatives were effective and therefore indicating an effective safety culture, it is hardly surprising that the company had poor risk awareness. The list at figure 8 highlights this issue perfectly; how could the company be aware of the risks they were taking if no analysis was given to the time saving measures adopted by the operations team? The National Commission made the following observation about BP's approach to risk; '*BP's management process did not adequately identify or address risks created by late changes to well design and procedures. BP did not have adequate controls in place to ensure that key decisions in the months leading up to the blowout were safe or sound form an engineering perspective*'.<sup>96</sup> This paper has found clear evidence that this phenomenon was not restricted to BP and that similar practices were endemic across the oil and gas industry. The next chapter will draw on the safety culture principles taken from the USN aviation domain and propose how they could be applied to the oil and gas industry as a whole.

### **CHAPTER FIVE**

Understanding the motivation behind the oil and gas industry when compared to the military aviation domain is key when addressing the fundamental difference between the two ventures. Financial reward comes first and foremost within the oil and gas industry and influences how drilling companies approach the concept of a safety culture. Also, the structure of the oil and gas industry is not

 <sup>&</sup>lt;sup>95</sup> Interview with very senior member of Department of Interior in post at the time of the Maconodo well accident.
 <sup>96</sup> Ibid, page 122

regimented; there is no rigid command structure that enhances leadership principles. The military has operationalized safety as a means of improving operational capability through its command structure. Although capability, or efficiency, within the oil and gas industry has improved through the adoption of a safety culture it takes a concerted effort, time and money to make a real impact. Operationalized safety requires total buy-in in order to be effective. In light of the recent financial impact of the Deepwater Horizon accident, BP is still recoiling from the financial implications<sup>97</sup> which are substantially higher than ever experienced before. With such a precedent, should the concept of operationalized safety be embraced by the oil and gas industry? Indications show that this concept may be taking root but the oil and gas industry will have to undertake a fundamental review of its approach to safety or remain vulnerable to another major accident occurring in the near term. This paper has clearly outlined the recurring lack of a safety culture within complex systems, as exemplified by the major accidents examined in chapter two, and the present activities of the oil and gas industry in the US. Reflecting on the lessons of military aviation, however, it is clear that change is possible. The military aviation domain has embraced the concept of operationalized safety as demonstrated by the marked improvement of USN aviation since 1952. The USN nuclear endeavor had no choice but to operationalize safety and has set the bar unrealistically high for other organizations to emulate and thus this paper posits that the oil and gas industry should not strive to achieve such goals. However, aspects of the operationalized safety approach to military aviation are well within the grasp of the industry.

The military aviation domain closely reflects diagram 3 which is an attempt to capture the essence of a safety culture. When this culture breaks down, such as the Nimrod accident examined in chapter three, the chance of a major accident is significantly increased. Specific from the diagram is the 'glue' that binds the safety process; the existence of an all-encompassing training environment. Training

<sup>&</sup>lt;sup>97</sup> BP has paid \$4.5bn to settle criminal charges, paid \$7.8bn in a settlement with people and businesses affected and could see the firm liable for up to a \$17.6bn civil fine.

is a key part of a military organization's routine and could be regarded as a luxury afforded to an organization not obliged to achieve financial targets. But this would be an unfounded observation as the military organization has limited resources and is driven to operate efficiently and therefore safely. Training sets specific standards that have to be met before individuals can advance to the next stage in their careers which in turn promotes a learning culture. The oil and gas domain in the USA does not benefit from such a structured training environment and relies more on 'on-the-job' training.

The military aviation domain is well regulated across all levels of the operation, from the aircraft handler or the weapons engineer to the pilot, all of whom have to reach certain standards during training and all are regularly tested to ensure they maintain proficiency. Not only does this enhance operational capability it builds trust and grows a safety culture. Regulation allows the senior leadership to monitor the operational capability of their fighting formations; any safety issues will soon be noted and exposed to the chain of command. The senior leadership also accepts that a fighting formation cannot maintain 100% fighting efficiency 100% of the time as new hands are absorbed and older experienced individuals depart on promotion. For example, a USN carrier is continuously undergoing a deployment/training cycle which starts with basic training for the individual operational components. The fleet squadrons assigned to the carrier will conduct work up training from a land base thus removing the complexity of deck operations and their progress will be regulated. At the same time, the deck crew responsible for the launch and recovery of aircraft will undergo basic training as will all other aspects of the ship. Once each area has reached the required level of proficiency, as dictated by regulations, they are then teamed up and commence training as a whole before a final test as a battle group<sup>98</sup>. Once this is successfully completed, which can take up to a year, the ship will commence a 6 month operational deployment. An oil rig is not a carrier employing approximately 3000 people but aspects of carrier

<sup>&</sup>lt;sup>98</sup> Modern carriers and future aircraft will be able to mitigate this stringent training regime through simulated processes and advanced technologies.

operations are very similar; both are tightly coupled and complex systems. However, the US oil and gas community, at the time of the Macondo well blowout were not afforded the benefit of an effective regulatory system as identified in chapter 4. The Wall Street Journal commented on this failure in 2010;

"Stephen Allred, who as Assistant Secretary of the Interior oversaw MMS from 2006 to 2009, said the agency does conduct spot checks...however, 'their role is not to baby-sit the operators', he said. The agency's primary task during inspections is to verify how much oil is being pumped, which is key to another MMS duty, maximizing payments the government receives for oil and gas rights from energy producers"<sup>99</sup>.

Once training is completed, operating standards are closely monitored across the military aviation domain and nuclear endeavor to ensure crews conform to prescribed standard operating procedures (SOPs). The SOPs are developed over time and absorb 'best practice' from across all operating platforms within that specific group; for example the 11 nuclear carriers, or the fleet of FA18 Hornet aircraft operated by the USN. When a new platform is introduced into the group, such as the imminent arrival of the F35, basic SOPs are designed by an Operational Evaluation and Test squadron with associated regulations designed to fit the specifics of that platform. In military aviation, nothing is left to chance and each identified risk is mitigated through applied thought and design. When one examines the approach that the oil and gas industry took towards drilling in the deep water of the Gulf of Mexico it is hard to identify such an approach. In fact, when the MMS attempted to raise revenue to offset the rising cost of training its staff to conduct increasingly complex inspections<sup>100</sup> they were overruled by Congress after pressure exerted by oil industry lobby groups. In fact, there was an; *'inconsistent and unstructured approach to information management....difficulties in determining and* 

<sup>&</sup>lt;sup>99</sup> Wall Street Journal, 'Oil Regulators Cede Oversight to Drillers', May 7, 2010.

<sup>&</sup>lt;sup>100</sup> The Federal Energy Regulatory Commission also "recovers the full cost of its operations through annual charges and filing fees assessed on the industries it regulates as authorized by the Federal Power Act (FPA) and the Omnibus Budget Reconciliation Act of 1986." http://www.ferc.gov/about/strat-docs/FY11-budg.pdf.

disseminating best practices, over reliance on long-service members of staff as sources of knowledge, cultural barriers between head office and regional staff, and duplication of effort between regions'.<sup>101</sup> The questionnaire used to gather information for this paper examines how the oil and gas industry embraced the concept of benchmarking and how the industry identified and absorbed best-practice. There was no consensus on how it did either. Nor was there evidence of any prescribed operating standards which is reflected in a report made by the International Association of Oil & Gas Producers (OGP);

'[A]ccording to OGP's Report on Regulators' Use of Standards, 1,140 different standards are referenced by the 14 regulators that were surveyed: 87% of these standards are referenced by only one regulator. This means that only 13% of the standards were referenced by two or more regulators, and implies an inconsistent application of standards among regulators'.<sup>102</sup>

High risk events within the military domain warrant specific focus in the pre-mission briefing and, in some instances, a pre-maneuver warm up. For example, before Basic Fighter Maneuver (BFM) training every pre-flight brief contains a thorough review of spin<sup>103</sup> recovery procedures with each member of the formation quoting a selected aspect of the drill by rote. The aim is to have each pilot 'programed' to undertake a pre-determined set of actions in the event he/she loses control of the aircraft during high energy BFM. In the case of emergency handling in larger aircraft, such as an engine failure during the take-off roll in a multi crew aircraft, each member of the crew will be required to complete a set of procedures which will have been briefed before the take-off roll has commenced. The point being, critical events have been identified prior to commencing a maneuver and the required

<sup>&</sup>lt;sup>101</sup> Offshore Minerals Management, Business Assessment and Alignment, report INT60TI, LMI Government Consulting, May 2007, p 5-3.

<sup>&</sup>lt;sup>102</sup> OGP, Regulators' Use of Standards (International Association of Oil & Gas Producers, Report No.45, March 2010).

<sup>&</sup>lt;sup>103</sup> A spin is the aerodynamic condition in which one or both wings have lost lift causing the aircraft to rotate about its axis and descend rapidly. In the case of a modern fighter aircraft a spin is an extreme condition.

recovery/emergency procedures have been thoroughly briefed. In the case of the Deepwater Horizon accident this was not the case. No walk through of a response to a blowout had been conducted; no briefing on who was responsible to activate the blowout preventer or even a review of how a 'kick'<sup>104</sup> would manifest itself when drilling at such an extreme depth. Interviewees from other rigs reinforced the observation that such critical-event pre-briefing or emergency discussions were not routine – there was an assumption that everyone knew what to do in the event of an emergency. *'The rig crew had not been trained adequately how to respond to such an emergency situation. In the future, well-control training should include simulations and drills for such emergencies – including the momentous decision to engage the blind shear rams or trigger the EDS.'<sup>105</sup>* 

There is clear evidence that the oil and gas industry's leadership approach to safety differs markedly to that within the USN. The need to make a profit is a clear delineator between the two ventures. However, the concept of an 'operationalized' safety culture, which runs through all levels of the USN, continues to enhance the operational effectiveness of the fighting force. The USN leadership operationalizes safety by embracing the core aspects identified within the safety culture diagram at figure 3. This chapter has shown that the oil and gas industry continues to fail to meet several of the key safety culture requirements laid out in figure 3 and in so doing fundamentally undermines the continued safety of its operations.

<sup>&</sup>lt;sup>104</sup> 'Kick' is the term given to the first stage of a blow out where hydrocarbon or gas has entered the return portion of the drilling process.

<sup>&</sup>lt;sup>105</sup> *Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling*, Report to the President, National Commission on the BP DWH Oil Spill, p122.

#### **CONCLUSION**

#### "O this learning, what a thing it is!"106

This paper has endeavored to offer a solution to the observation made in the National Commission Staff Working paper 21; "Industry and government should investigate other actions and programs that might help promote, sustain, and monitor a culture of safety achievement"<sup>107</sup>. The key to approaching this question was first to establish a link between the oil and gas industry and the military aviation domain. Without a clear link any observations would be met with skepticism. Chapter one conclusively demonstrated that both endeavors are complex and tightly-coupled systems which are prone to the same type of failure, be it design or from human failings. The comparison conducted by this paper is therefore highly pertinent and the observations deserve further analysis. The central observation remains that comprehensive strategic leadership is fundamental in ensuring that a safe and effective working environment exists across complex working environments such as oil and gas extraction and the military aviation domain. A failure for strategic leadership to embrace a safety culture is reinforced by the following statement taken from the Report to the President on the BP Deepwater Horizon oil spill which specifies a failure of management:

"The most significant failure at Macondo – and the clear root cause of the blowout – was a failure of industry management. Most, if not all, of the failure at Macondo can be traced back to the underlying failures of management and communications. Better management of decision making processes within BP and other companies, better communication within and between BP

<sup>&</sup>lt;sup>106</sup> William Shakespeare, *The Taming of the Shrew*, Gremio, Act 1 Scene2.

<sup>&</sup>lt;sup>107</sup> National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, A Competent and Nimble Regulator: A New Approach to Risk Assessment and Management, Staff Working Paper No.21.

and its contractors, and effective training of key engineering and rig personnel would have prevented the Macondo incident".<sup>108</sup>

Chapter one also investigated the concept of a safety culture and offered up a proposal in figure 3. The paper used this model as a prism to view both the oil and gas industry and military aviation domain in order to conduct a level of analysis. The chapter also examined the USN nuclear endeavor as it, arguably, operates within the most comprehensive safety culture and was offered up by interviewees as a benchmark towards which they aspire. The USN nuclear endeavor is a working example of Heinrich's triangle, as demonstrated at figure 4, albeit one with a prohibitively 'high bar' for the commercial sector to emulate.

It would be wrong to conclude that the failure of strategic leadership is a problem unique to the Macondo well blow-out. The analysis of five major accidents in chapter 2 exposed an underlying trend of failure at the strategic level which has an unfortunate tendency of repeating itself through history. More importantly, however, was the overwhelming interview consensus that the Macondo accident could have befallen any one of the companies drilling in the deep water of the Gulf of Mexico. This provides strong evidence that the failings at the strategic level were not unique to this incident or to the BP leadership.

Having established the link between the two activities, developed a model that captured the essence of a safety culture and distilled the recurring themes of strategic failure through the analysis of five major accidents the paper turned its focus on the strategic leadership of the military aviation domain. The overarching concept that underpins military aviation is the need to operationalize safety; without a functioning safety culture, military aviation would be untenable. The graph at fig 6 shows the

<sup>&</sup>lt;sup>108</sup> *Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling*, Report to the President, National Commission on the BP DWH Oil Spill, p122.

profound effect of adopting such an approach but it also demonstrates that developing a safety culture is a generational challenge. In order to make that generational change the USN adopted a form of selfregulation through the NATOPS system which revolves around 2 key tenets; leadership and training. The NATOPS system embraces, to some degree, the Heinrich triangle concept shown at figure 4 which thrives on 'total training', from strategic leadership to the deck operators employed on the Carrier flight decks. In essence, NATOPS sets the regulatory foundation, the prescribed training events, the expected standards and standard operating procedures which transcend all working and leadership levels of the USN surface fleet community. As outlined in chapter one, the USN nuclear endeavor embraces the concept of Heinrich's triangle and sets a very high bar. In chapter three the USN nuclear endeavor is explored further to see if it is a tenable example for the oil and gas industry to adopt. However, this paper concludes that the level of effort required to reach this 'gold standard' of safety culture may be financially prohibitive for the oil and gas industry to emulate although the key aspects are reflected in the military aviation domain which sets a more achievable model.

The paper then turned its focus onto the Deepwater Horizon accident and compared it to the 7 key failings set out in figure 5. The key observation was the company's acceptance to continue exploratory drilling when regulations for this dangerous regime were clearly inadequate<sup>109</sup>; if they purported to be a safety orientated venture why would they be content to push the boundaries to drill in the deep waters of the gulf with no clear regulatory guidance? This paper proposes that financial goals overwhelmed the development of a rigorous safety case for the Deepwater Horizon. In fact, any attempt by the MMS to raise funding in order to stay abreast of the fast developing deep water frontier were undermined by oil-company funded lobby groups.

<sup>&</sup>lt;sup>109</sup> All oil and gas companies drilling to the same depth are guilty of this infraction.

The safety diagram at figure 3 clearly shows that training is the glue that enables a safety culture. This paper has demonstrated that there is no industry-accepted level of training that serves the development of a safety culture. On-the-job training and experience based operations cannot be regarded as an adequate approach to the demands of a safety culture. The paper also examined the applicability of the Heinrich triangle in serving the oil and gas industry's approach to developing a safety culture. There was no written evidence that the oil and gas industry were actively embracing the concept but there was plenty of evidence that the industry was monitoring minor personal incidents as a method of measuring safety. Although not definitive, this paper offers the view that within the oil and gas industry the model may be suffering from a 'fractured effect' where the tactical level is isolated from the strategic level by a company safety-organization led processes. The paper concluded that at the lower levels, individuals are inundated with safety initiatives which serve to undermine the relationship between a company's safety regime and those at the tactical level of the operation. This in effect isolates the strategic level and undermines the development of a complete strategic culture across all aspects of the industry. This phenomenon is ironically exemplified by the Deepwater Horizon operators who, at the time of its demise, were about to receive a safety award for achieving high levels of personal safety. This paper posits that the oil industry confuses tactical safety initiatives for strategic safety awareness which was clearly demonstrated in the Deepwater Horizon accident. This effect is accentuated by the inadvertent fracturing of the Heinrich triangle model by the empowered safety organizations of oil companies. Compounding this phenomenon was the accepted practice of oil rig workers avoiding promotion in order to retain what they considered to be more acceptable remuneration and working routines. This resulted in the possible promotion of inadequately experienced individuals, with limited training, into positions of authority.

This paper argued that the leadership demonstrated by the strategic level of the oil and gas industry is inextricably linked to the regulation provided by the government. At the time of the

61

Deepwater Horizon accident, the MMS had become an inadequately resourced authority unable to meet the growing demands of regulating exploration drilling in the deep waters of the Gulf of Mexico. It appears that the industry as a whole was content for this condition to endure and continued to exploit the inadequate level of regulation. The industry's poor risk awareness compounded by the lack of regulation resulted in the strategic leadership unable to grasp the true level of risk being taken by their respective companies. Ultimately, the oil and gas industry, including the government regulators, had failed to develop a safety culture that would have served to avoid the Deepwater Horizon accident.

In the final section this paper observes that the financial drivers for the oil and gas industry are fundamentally different from those affecting the military aviation domain although there is clear evidence that the oil and gas industry would benefit from the concept of an operationalized safety culture as embraced by the military aviation community. It is this concept that underpins all of the observations within this paper; in the case of the military such a concept enhances operational capability whereas the oil and gas industry would benefit from increased efficiency. More importantly, the oil and gas industry, through an operationalized safety culture, would benefit from an increased resilience against catastrophic accidents which are becoming increasingly more financially damaging. In order to emulate the military's operationalized safety concept the oil and gas industry need to embrace regulation and work in concert with the government to produce mutually acceptable structures that would work within USA's free market climate. In parallel, the industry needs to address the concept of training; the application of a NATOPS structure may be too much for the market to bear but an accepted pan-industry training structure should be a target that the industry deems worth aspiring to. A quick win would be the adoption of pre-briefing emergency procedures prior to any critical high risk event such as handling a kick and blow-out prevention actions as well as identifying who has the responsibility to activate the emergency blowout preventer valve. These actions can be predetermined and be outlined on reference cards much like those used in aircraft cockpits.

62

There is no doubt that there is an appetite within the oil and gas industry for improvement as highlighted in a speech given by the CEO of ExxonMobil; *'To get where we need to be on safety, continuous improvement is essential. In an industry such as ours, which operates 24 hours a day around the world, the need to manage risk never ends"*<sup>110</sup>.

As exploration boundaries continue to expand with the development of ever more complex drilling techniques allowing the extraction of hydrocarbons from previously inaccessible areas, risks will continue to grow to match complexity. Fragile environments, such as the arctic ice cap, are being investigated for future exploration. The need, therefore, of an operationalized safety culture becomes ever more pressing as the oil and gas industry seeks to understand the risks associated with the development of cutting edge extraction techniques. However, an operationalized safety culture requires strategic leadership not just the application of sound management principles. In the words of the National Commission on the Deepwater Horizon accident; *'The root causes [*of the accident*] are systemic and, absent significant reform in both industry practices and government policies, might well recur'.*<sup>111</sup> This paper offers an approach that might well assist in that reform process.

<sup>&</sup>lt;sup>110</sup> Rex Tillerson, CEO ExxonMobil, 9<sup>th</sup> November 2010.

<sup>&</sup>lt;sup>111</sup> *Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling*, Report to the President, National Commission on the BP DWH Oil Spill, p122.

# BIBLIOGRAPHY

BP Deepwater Horizon Accident Investigation Report, 8 Sep 2010.

Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) 1 Oct 2011.

CNO cover note, OPNAV INSTRUCTION 3710.7U dated Nov 23 2009.

Conference Summary, International Regulators' Forum, http://www.irconference2010.com/showcontent.aspx?MenuID=940

Haddon-Cave, Charles QC. An independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 aircraft XV230 in Afghanistan in 2006, 2009, London: HM Stationary Office.

HM Stationary Office. *Department of Transport Formal Investigation into mv Herald of Free Enterprise*, report of Court No. 8074, London, 1987.

Investigation Board, Columbia Accident Report, August 2003.

Investigation Board, U.S. Chemical and Hazard, *Investigation Report BP Texas City* Report No.2005-04-I-TX, 2005

McDermid, J A, PHD, *Through Life Safety Management: Some Concepts and Issues*, University of York, 2007.

National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, A Competent and Nimble Regulator: A New Approach to Risk Assessment and Management, Staff Working Paper No.21.

National Commission on the BP DEEPWATER HORIZON Oil Spill, *Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling*, Report to the President, January 2011,

Occupational Radiation Exposure report NT-12-2, May 2012 PAGE 35

Offshore Minerals Management, Business Assessment and Alignment, report INT60TI, LMI Government Consulting, May 2007,

Pate-Cornell, M E, A Post-Mortem Analysis of the Piper-Alpha Accident, Stanford University, 1991.

Perrow, Charles, Normal Accidents, Princeton University Press, 1999

Reason, James *Managing the Risk of Organizational Accidents*, (Ashgate Publishing Company, UK – 1997).

----- The Human Contribution, (Ashgate Publishing Company, UK, 2008).

Sagan Scott D, The Limits of Safety, 1993, (Princeton University Press, 1995).

Shakespeare, William, *The Taming of the Shrew*, Gremio, Act 1 Scene2.

Sutcliffe, Kathleen and Karl Weick, *Managing the Unexpected*, (Jossey-Bass publishing, 2007).

Thompson, James, Organizations in Action, (New York: McGraw-Hill, 1967).

UK Crown - A review of safety culture and safety climate literature for the development of the safety culture inspection toolkit, Human Engineering – HSE Books, 2005, Report 367. UK Crown.

US Energy Information Administration, <u>www.eia.gov/tools/faqs/faq.cfm?id=33&t=6</u>, 26 Feb 2013.

Wall Street Journal, 'Oil Regulators Cede Oversight to Drillers', May 7, 2010.