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Center for Catastrophic Risk Management
Department of Civil and Environmental Engineering
212 McLaughlin Hall
Berkeley, California 94720-1710
Tel: (510) 642-0960
ce.berkeley.edu

Robert Professor Robert Bea, Ph.D., P.E.
Deepwater Horizon Study Group
Tel: (510) 643-8678
Fax: (510) 643-8919
bea@ce.berkeley.edu
ccrm.berkeley.edu

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National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling
1 Thomas Circle, N.W.
Washington, D.C. 20005

Dear Commissioners:

The Deepwater Horizon Study Group submits these comments on the Commission's preliminary technical and managerial conclusions presented on November 8 and 9, 2010. In light of these conclusions and our analyses related to the Deepwater Horizon explosion and fire during the past seven months, we provide specific recommendations to help ensure that future offshore drilling in "new frontier" areas will operate within acceptable levels of risks.

The Deepwater Horizon Study Group, formed in May 2010, is organized under the auspices of the Center for Catastrophic Risk Management at the University of California, Berkeley. It is comprised of more than 60 experienced professionals, experts, and scholars in the fields of offshore drilling and operations, geology, accident investigations, organizational management, governmental regulatory affairs, system safety and reliability, risk assessment and management, marine ecology, environmental science, and law.

As noted in the attached comments, the Study Group concurs with the correctness of the Commission's technical findings related to the flow path, cement failures to isolate the hydrocarbons, inappropriate reliance on inadequate negative pressure tests, and the additional risk created by BP's temporary abandonment procedures. We agree with the Commission that any technical conclusions related to the role of the blowout preventer should await further forensic testing of the equipment. The Study Group does not conclude those who worked on the Deepwater Horizon Macondo well project made conscious 'well informed' decisions to trade safety for money. Analysis of the available evidence indicates that when given the opportunity to save time and money – and make money – tradeoffs were made for the certain thing – production – because there were perceived to be no downsides associated with the uncertain thing – failure caused by the lack of sufficient protection. Thus, as a result of a cascade of deeply flawed failure and signal analysis, decision-making, communication, and organizational - managerial processes, safety was compromised to the point that the blowout occurred with catastrophic effects.

The oil and gas industry is embarking on an important "next generation" series of exploration and production operations in the ultra-deep waters of the Gulf of Mexico, the remote waters of the Arctic, and other new frontier areas. Oil and gas development will continue to pose risks, with concurrent likelihoods and consequences of catastrophic failures, that are several orders of magnitude greater than previously confronted by regulators, the industry, and society. The significant increases in risks are due to: (1) complexities of hardware, software, emergent technologies, and human systems used in these operations, (2) natural hazards posed by the ultra-deepwater marine environment, including geologic, oceanographic, and meteorological conditions, (3) hazards posed by the physical properties of hydrocarbon reservoirs, such as high productivities, pressures, temperatures, gas-to-oil ratios, and low strength formations, and (4) the sensitivity of the marine environment to introductions of large quantities of hydrocarbons.

The disaster of the Macondo well, with its loss of life, injuries, and uncontrolled blowout, demonstrated the consequences of preventable major system failures. The Deepwater Horizon incident was caused, in part, because BP failed to follow several key industry best practices related to well construction, well control, and secondary emergency systems. These voluntary practices were not mandated by law or regulations. Further, to the extent that critical safety-related regulations existed, such as for blowout prevention plans, the Minerals Management Service (MMS) waived these key requirements for Deepwater Horizon.

Thus, major “step change” improvements are required to ensure offshore exploration, production, and transportation activities operate within acceptable levels of risks. Based on our findings thus far on the causes of the Deepwater Horizon incident and lessons gleaned from the nuclear industry, aviation industry and other high-performing, high-risk industries, we encourage the Commission to recommend the following reforms to help to prevent future disasters:

1. **Regulatory Roles and Functions -** Jurisdiction and responsibilities must be clarified to resolve current uncertainties regarding the regulatory and inspection roles of the U.S. Coast Guard, the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE), the Occupational Safety and Health Administration (OSHA), the Environmental Protection Agency (EPA), as well as the respective state agencies under the Coastal Zone Management Act (CZMA) in regulating offshore oil and gas development. Additionally, with regard to oil spill response, the National Response Framework and applicable legislation such as the Oil Pollution Act and the Stafford Act need to be better integrated. Further, BOEMRE should enact a rule to clarify and coordinate responsibilities at multi-employer worksites and ensure compliance with applicable regulations and procedures by the permit holder and its contractors, subcontractors, and service providers. BOEMRE should maintain oversight of the contracts between the permit holder and its contractors and other service providers to ensure that any fee incentives based on reduced time and costs of performance do not compromise the professional quality of the contracted work in ways that would undermine operational safety. Any regulatory reforms should promote the adoption of an adaptive regulatory model capable of dealing with the increasingly sophisticated and complex systems. Such reforms could include an independent regulatory agency funded by oil and gas development royalties and fees; a Safety Case based systems-focused approach to regulatory oversight of safety and emergency systems; risk-informed decision-making; improved training and qualification programs for inspectors; operational monitoring by onsite inspectors; and industry-wide “whistle-blower” protections.

2. **NEPA and Worst-Case Blowout Scenario -** Compliance by BOEMRE and permit applicants, pursuant to the National Environmental Policy Act (NEPA), must be based on context-specific and activity-specific information and estimations of the reasonably foreseeable impacts of routine operations, accidents, and other non-routine incidents on the human and natural environments. In addition, a worst-case scenario that reflects technical expertise and the plausible concerns of stakeholders and local communities whose interests may be impacted must be evaluated by BOEMRE as part of the NEPA process and subsequently be used for the purpose of determining whether a permit will be granted with

special conditions for minimizing the likelihood of the worst-case scenario and for minimizing its impacts if it does occur.

3. **Worker Safety and Health -** Priority should be given to resolving current uncertainties regarding regulatory and inspection roles of BOEMRE and the U.S. Coast Guard for worker safety and health and to enacting a process safety management rule with provisions for change management, as similar to OSHA's process safety management rule for onshore oil and gas operations. In assuming responsibilities for worker safety and health, BOEMRE should enact workplace safety and health regulations that are integrated with and reinforce its accident prevention requirements, and not assume that accident prevention requirements alone provide sufficient protection for worker safety.

4. **Stop Work Authority -** BOEMRE should require by rule that a worker safety representative be appointed at each installation to participate in operational decisions and be empowered to suspend operations when the representative believes in good faith that continuation of operations would imminently endanger worker safety. These are key features of proven value in the Norwegian regulatory approach to offshore safety.

5. **Safety and Environmental Management System (SEMS) -** BOEMRE's new SEMS rule marks the first time that a federal agency will directly regulate the structure and core functions of the safety management system of an offshore operator. The SEMS rule mandates operator fulfillment of eleven broadly stated safety management functions, as well as compliance with other self-auditing, documentation, and reporting requirements. The rule also explicitly requires operators to implement and to comply with standards and practices developed by the American Petroleum Institute (API) and other standard-setting organizations or risk regulatory enforcement action for noncompliance. This new approach raises several issues that need to be addressed by BOEMRE:

    a) Given that each company's fulfillment of the functional, performance-based requirements will be based, in part, on consideration of the special features of its operation, and thus differ in several respects from what other companies do for compliance, BOEMRE needs to ensure that each company's compliance with SEMS affords equivalent protection for workers and the environment.

    b) The current checklist approach to inspection, whereby relatively inexperienced inspectors police companies for potential incidents of noncompliance with prescriptive technical standards and rules, is inadequate for evaluating compliance with the broadly-stated functional requirements of the SEMS rule. Therefore, BOEMRE needs to ensure that inspections pursuant to the SEMS rule are conducted by highly qualified personnel capable of fully evaluating companies' efforts to meet the performance-based functional requirements and capable of offering regulatory guidance, as necessary.

    c) BOEMRE also must ensure that the safety standards and recommended practices relied upon by companies for compliance with the SEMS rule, such as those defined by the American Petroleum Institute (API) and other standard-setting organizations, are qualitatively sufficient in terms of the technical state of the art and are not compromised by the economic interests and lobbying activities of the membership of these standard-setting organizations. Because the procedures used by such organizations for developing standards and recommended practices are not transparent, nor do the procedures generally permit access by non-industry stakeholders, BOEMRE should also conduct transparent "regulatory forums" in which existing and proposed standards and best practices related to the SEMS rule are discussed with participation by non-industry stakeholders.

6. **Cost-Benefit Analysis -** BOEMRE should secure the cooperation of the Office of Information and Regulatory Affairs (OIRA) within the Office of Management and Budget (OMB) to ensure that enactment of new regulations necessary for accident prevention are not obstructed by unduly stringent applications of cost-benefit analyses.

7. **Independent Organization to Evaluate Drilling Operations –** An independent organization, established and funded by industry and government, could perform evaluations of drilling and production operations.

8. **Safety Culture Advisory Committee -** BOEMRE should establish an interdisciplinary advisory committee on safety culture to give meaning to this important concept and provide guidance for its establishment and maintenance by the variety of public and private stakeholders involved in offshore drilling. Thus far, the concept has never been clearly defined. The advisory committee could address the role of the following elements in the promotion of safety: organizational learning from accidents and near miss-incidents, internal reporting, ethics in decision-making, leadership in promoting continuous improvements, and guidelines used in other industry sectors to implement and measure safety criteria, systems, and outcomes.

9. **Industry-Wide Emergency Response Capability –** Greater industry-funded oil spill response capability will help to ensure preparedness for a worst-case scenario. Options include an industry-funded network of oil spill response operators or a requirement for companies to commit specific equipment, supplies, and staff to respond when the responding company's capabilities would be inadequate due to the disaster's scale.

10. **Industry-Funded Accident Insurance Pool –**An industry-funded accident insurance pool could supply a guaranteed source of funds to pay for compensation for loss of life and injuries, environmental cleanup, and economic damages.

The Study Group is developing a series of more than thirty Working Papers related to the Deepwater Horizon incident and its lessons for future offshore drilling. These forthcoming Working Papers will be available in January 2011. The Study Group will issue its final report in Spring 2011 and will provide an online public archive for the data, documents, and information obtained during this study.

Thank you for the opportunity to provide comments. Expert members of the Study Group, including myself, are available to answer questions that the Commission and its staff may have about our submitted comments or our forthcoming publications. We commend the Commission for its ongoing dedication to investigate the root causes and to provide well-informed insights and information on the failures behind the Deepwater Horizon incident. We look forward to the Commission's forthcoming report.

Sincerely,

Professor Robert Bea, Ph.D. P.E.
Deepwater Horizon Study Group

Deepwater Horizon Study Group Members

Thomas Azwell, Doctoral Student, Researcher, Department of Environmental Science, Policy, and Management, University of California, Berkeley.

Michael Baram, LL.B., Professor Emeritus, Boston University Law School, Boston, Massachusetts.

Robert G. Bea, Ph.D., P.E., Professor, Department of Civil and Environmental Engineering, University of California, Berkeley.

Michael J. Blum, Ph.D., Arnold Early Career Professor in Earth and Ecological Science, Department of Ecology and Evolutionary Biology, Tulane University, New Orleans, Louisiana.

K. Florian Buchler, LL.M., Attorney at Law (Germany), Tulane University, Buchler & Co**.,** New Orleans, Louisiana.

W. E. Carnes, M.A., B.S., Practitioner Associate, Center for Catastrophic Risk Management, Haas School of Business, University of California, Berkeley.

Paul Donley, Corporate Trainer, Programer, Web Developer, Relevant Training, Melbourne, VIC Australia

Yngvar Duesund, Special Advisor to the Center for Information Technology Research in the Interest of Society, The Banatao Institute—CITRIS, University of California, Berkeley.

William E. Gale Jr., Ph.D., P.E., CSP, CFEI, CFII, Forensic Engineering Consultant, President, William E. Gale, Jr., Inc.; Principal, Bundy, Gale & Shields LLC, Novato, California.

Ove T. Gudmestad, Ph.D., Professor, Faculty of Science and Technology, University of Stavanger, Stavanger, Norway.

Anthony Hare, Psy.D., Executive Director, Center for Catastrophic Risk Management, University of California Berkeley.

Samantha Joye, Ph.D., Professor**,** Department of Marine Sciences, University of Georgia

Jahon Khorsandi, M.S.E., Graduate Student Researcher, Center for Catastrophic Risk Management, University of California, Berkeley.

Kennith Kotow, P.E., Senior Associate, Successful Energy Practices International, San Antonio, Texas.

Trevor A. Kletz, D.Sc., Visiting (Adjunct) Professor, University of Loughborough, United Kingdom.

Sindhu Kubendran, B.S., Research Associate, University of California, Berkeley.

Kevin Lacy, B.S., Petroleum Engineering, M.B.A., Senior Vice President, Global Drilling and Completions, Talisman Energy, Calgary Alberta, Canada.

Artin Laleian, Student, Research Associate, University of California, Berkeley

Gary Marsh, B.S.M.E., Retired, Shell Drilling Engineering Advisor, Houston, Texas.

Wayne Needoba, B.S., P.E., Consultant on Drilling, Project Coordination, Learning, Competence Assessment, Labrador Holdings WA, Perth, Western Australia; Managing Director, LIS Thailand Co., Chiang Mai, Thailand.

Scott Nicholson, Doctoral Graduate Student Researcher, Engineering Policy Analysis and Environmental Planning, University of California, Berkeley.

Michael L. Olson, Ph.D., P.E., Innovation, Sustainability, and Change Management Consultant, Walnut Creek, California.

David M. Pritchard, B.S, P.E., Owner, Successful Energy Practices International LLC, San Antonio, TX

Karlene Roberts, Ph.D., Professor Emeritus, Haas School of Business, Director, Center for Catastrophic Risk Management, University of California, Berkeley.

Emery Roe, Ph.D., Research Associate, Center for Catastrophic Risk Management, Haas School of Business, University of California, Berkeley.

Paul Schulman, Ph.D., Research Associate, Center for Catastrophic Risk Management, Haas School of Business, University of California, Berkeley.

Jon Espen Skogdalen, M.S.E., Research Fellow, Visiting Fulbright Scholar, Department of Civil and Environmental Engineering, University of California, Berkeley; Research Fellow, Doctoral Student, Faculty of Science and Technology, University of Stavanger, Norway.

Liz Taylor, President, DOER Marine, Alameda, California.

John Thomas III, Law Student, Golden Gate University School of Law, San Francisco, California.

Marianne Tiffany, B.Sc., School of Psychology, the University of Aberdeen, Aberdeen, Grampian, United Kingdom.

Ingrid B. Utne, Ph.D., Visiting Scholar, Department of Mechanical Engineering, University of California, Berkeley; Professor (Qualification Fellowship), Department of Marine Technology, Norwegian University of Science and Technology, Trondheim, Norway.

Jan-Erik Vinnem, Ph.D., Professor II, Faculty of Science and Technology, University of Stavanger, Norway.

Ed Wenk Jr., Ph.D., Emeritus Professor of Engineering, Public Administration and Social Management of Technology, University of Washington at Seattle, Washington.

LuAnn E. White, Ph.D., DABT, Tulane University School of Public Health and Tropical Medicine, New Orleans. LA

APPENDIX A

Deepwater Horizon Study Group

Center for Catastrophic Risk Management at the University of California, Berkeley

Commentary on National Commission Investigators' Preliminary Technical & Managerial Conclusions of November 8 and 9, 2010

TECHNICAL CONCLUSIONS

Conclusion: Flow path was exclusively through shoe track and up through casing.

Comment: This mode of failure was one of the two primary modes of failure analyzed by the DHSG.[1] The evidence available at this time indicates the flow path through the bottom casing assembly and cement is the most plausible mode of failure that led to the blowout. The physical evidence of the recovered casing head seal assembly, the failed negative pressure test, and the post-hoc analysis of the cement slurry test data conducted by Chevron support this as the most likely flow path scenario.

Alternatively, if the flow path did not develop through the shoe track and up thorough the casing, it could have developed up the outside of the long-string production casing (channeling through fractures in the failed cement), flowing up the annulus and to the production casing hangar at the seafloor. Expanding hydrocarbons could have found their way into the riser through the unsecured casing hangar at the seafloor due to pressures in the annulus; however, the absence of external erosion and damage on the outside of the casing hanger seal assembly and its orifices does not support this alternative hypothesis. Another low probability leak path into the production casing bore could have been a breach developed in one of the slim-line production casing connections. A vulnerability was created by not cleaning, inspecting, and then protecting metal-to-metal seals in the casing connections when they were deployed.

Conclusion: Cement (potentially contaminated or displaced by other materials) in shoe track and in some portion of annular space failed to isolate hydrocarbons.

Comment: The available evidence indicates the "experimental" nitrogen foamed cement, the pre- and post- cementing processes (e.g. partial bottoms up circulation, positive pressure testing before cement cure), the hardware used near and at the bottom of the long-string production casing (e.g. minimum centralizers, float collar and shoe, the characteristics of the well at the bottom (e.g. clearance between production casing and weak formation, clearance between the bottom reamer and the bottom of the well – the "rat hole"), and the reservoir characteristics (high pressures, high temperatures, gaseous hydrocarbons, relatively weak formation) all contributed to failure of the cement near and at the bottom of the Macondo well.[2]

[1] G.L. Marsh, "Analysis of MC 252#1 Well Blowout, DHSG Working Paper.
[2] G.L. Marsh, "Cementing 7" x 9-7/8" Production Casing at MC 252#1 Well, DHSG Working Paper.

Conclusion: Pre-job laboratory data should have prompted redesign of cement slurry.

Comment: The available evidence indicates that the cement slurry ingredients, mixing, placement, and curing characteristics were the result of a series of laboratory experimental and analytical processes that did not develop acceptably reliable results for the Macondo well completion conditions and processes. This design did not meet the Best Available and Safest Technology requirements of the lease and well permit requirements.[3] The use of micro-sized high pressure resistant glass beads rather than nitrogen to achieve a stable lightweight cement mix could have had higher reliability for these conditions.[4] Given the important differences between the prototype conditions at the bottom of the Macondo well and those in the laboratory and simulated on the computer, there should be continuing major concerns for the reliability of this critically important part of wells to produce hydrocarbons in high hazard reservoir environments.

Conclusion: Cement evaluation tools might have identified cementing failure, but many operators may have decided not to run tools at that time and relied only on the negative pressure test.

Comment: Without a trip to drill out the float equipment and shoetrack, the Cement Bond Log (CBL) tools could not have been used to evaluate cementing quality except that opposite a few 'stray' sands above the main body of hydrocarbon bearing strata. In addition, it would have been necessary to provide about 72 hours minimum curing time on the cement to have the best chance at a useful log trace. A lot of time and money would have been spent in preparing for and running a CBL log. Although it may have given clues to latent defects, the trace itself is subject to interpretation in many cases. If properly planned, conducted, and interpreted, the negative test could have safely yielded a more direct and therefore more certain assessment of defects.

The critical decisions were: 1) not running the production casing as a liner to provide the best chance of obtaining multiple barriers, and 2) trusting the cement and not having processes and procedures which do not leave safety and reliability to chance in the event the barriers prove faulty.[5]

Had the Macondo well not failed through the inside of the bottom assembly, then another mode of failure could have developed outside of the casing due to channeling through the narrow sheath of cement above the bottom of the well. Failure of the cement outside of the long-string would allow the producing formations to charge the annulus of the long-string with hydrocarbons. In this case, well logging – cement evaluation tools could have provided early warnings of deficiencies in the cement sheath above the bottom of the well which could have been remediated before the well was temporarily abandoned.

There are many possible ways a well 'structure' can fail. Multiple lines of defense – or barriers – should be in place to develop a 'robust' - damage and defect tolerant - structure. In addition, multiple sensing processes should be used to disclose important

[3] DHSG Progress Report 1, May 24, 2010.
[4] G.L. Marsh, "Cementing 7" x 9-7/8" Production Casing at MC 252#1 Well," DHSG Working Paper, 2010.
[5] G.L. Marsh, "Final Fateful Flaws," "Mistakes – Omissions on Macondo Well," "What Might Have Been – Risk Assessment and Management Analysis (RAM) of BP Tapered Production Casing Plan," DHSG Working Papers, 2010.

'latent defects' so they can be remediated before they are activated to help cause failures.[6]

Conclusion: Negative pressure test(s) repeatedly showed that primary cement job had not isolated hydrocarbons. Despite these results, BP and Transocean treated negative pressure tests as a complete success.

Comment: This experience provides a classic example of tests and the analyses of those tests developing 'false positives.' The combination of the signals or data provided by the test and the analyses of those tests falsely indicates there is no significant likelihood of failure in the well structure. This type of 'system' failure involves a combination of factors emanating from the operating teams, their organizations, the hardware (e.g. instrumentation, data displays, communications), procedures (formal, informal), environments (external, internal, social), and interfaces among the foregoing.[7] The information exists, but is not properly accessed and evaluated, or if it is properly accessed, it is not properly understood (unknown knowable). There are a wide variety of reasons for such 'cognitive' (thinking, sensemaking) malfunctions. One of the most important is 'conformational bias' – what we see and think is what we expect to see and want to think (wishful thinking).

It is debatable whether the cement job ever had a chance to achieve isolation given the large pressure reversal from the top stray zones to the bottom – what is not debatable is understanding the risk of actually executing a successful cement job – and planning remedial measures accordingly.

Conclusion: BP's temporary abandonment procedures introduced additional risk

Comment: The revised temporary abandonment procedure was proposed to the MMS on April 14, 2010 and approved by the MMS on the same day. Additional changes were made, all of which added to the risks associated with the temporary abandonment procedure. The available evidence and testimony indicates the temporary abandonment procedure had several parts that were of major concern to the Transocean drill crew and Offshore Installation Manager. The revised temporary abandonment procedure was introduced in the final days of completing the drilling of the Macondo well. The temporary abandonment procedure involved major changes from completing the well as an exploratory well to completing it as a production well as the Commission investigators clearly documented in their Master Presentation. Such modifications were made to expedite 'early production' from the prolific hydrocarbon formations that had been discovered at this location.

The temporary abandonment procedure was designed to make the completion activities more efficient (save time and money) by 'early' displacement and offloading of the drilling mud and running of an all-in-one tapered casing string extending from the bottom

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[6] R.G. Bea, "Risk Assessment and Management: Challenges of the Macondo Well Disaster," Y. Duesund and O.T. Gudmestad, "Deepwater Well Design, Competency – Management of Risks," D.M. Pritchard and K. J. Kotow, "The New Domain in Deepwater Drilling: Applied Engineering and Organizational Impacts on Uncertainties and Risk," D.M. Pritchard and K. Lacy, "Deepwater Well Complexity – The New Domain," J.E. Skogdalen, I.B. Utne, J.E. Vinnem, "Looking Back and Forward: Could Safety Indicators Have Given Early Warnings About the Deepwater Horizon Accident?," D.M. Pritchard, "Targeting Problematic Deepwater Drilling Operations," DHSG Working Papers, 2010.
[7] R. G. Bea, "Risk Assessment and Management: Challenges of the Macondo Well Disaster," "Managing Rapidly Developing Crises – Real-Time Prevention of Failures," DHSG Working Papers, 2010.

of the well to the sea floor wellhead. But these plans were not well thought out with little or no objective Risk Assessment and Management (RAM) process in planning, and failure to follow accepted Management of Change (MOC) procedures. The RAM and MOC approaches taken together yield appropriate Process Safety, which in this case was sadly lacking.

The all-in-one tapered production casing string was a ‘minimum structure’ that did not provide the additional ‘barriers’ that a liner and tie-back to the casing above would have. This long-string design was thought to save both time and money, but was not thought by BP and the MMS to be riskier than a liner and tie-back completion structure. If all had gone according to plans and the conditions were as anticipated, then that assessment could have been realized. However, the conditions were not as anticipated and the plans resulted in flaws and defects that defeated this minimum well structure. Minimum structures are not robust structures able to tolerate initial uncertainties and damage and defects introduced during the life of the structure.

The parts of the temporary abandonment procedure that did result in a substantial increase in risk were: (1) the lack of engineering guidance on expected results and interpretation in the planning for the underbalanced test, (2) conducting the test before the bulk of cement had time to develop strength, and (3) the plan to under-balance test with the drill string 10,000 feet off bottom. Whether the surface plug was planned to be 300 ft below mud line or 3300 feet is almost immaterial. A robust under-balance must be used to provide meaningful results in either case to confirm barrier(s) before the heavy mud in the long drill riser can be prudently removed.. This test procedure required that the well be under-balanced – the external (zonal) pressures acting on the well at the bottom would be greater than the internal pressures inside the well structure. If the ‘plugs’ at the bottom of the long-string well structure (cemented shoetrack and flapper float collar) were reliable, if the external ‘seals’ (cement sheath, casing body and connections and casing hangar seal, provided for that long-string well structure were reliable, and if no hydrocarbons had been allowed to enter the well bore during the completion work and reside in the drill column, then the temporary abandonment procedure could have worked as expected. However, the evidence indicates that the provisions for isolation at the bottom of the well did not provide a reliable barrier and that hydrocarbons entered the well bore during the long-string completion and temporary abandonment processes. When the well was progressively under-balanced by displacing the heavy drill mud in the upper 8,300 feet with much lighter sea water, the hydrocarbons in the well bore migrated undetected to the surface with ensuing catastrophic effects.

Conclusion: Number of simultaneous activities and nature of flow monitoring equipment made kick detection more difficult during riser displacement.

<u>Comment</u>: Important simultaneous activities included work on and around the drill floor and mud pits associated with completion of the temporary well abandonment procedures and preparing for the next well. Activities included transferring drilling mud from the Deepwater Horizon to the Damon Bankston supply vessel, performing a ‘sheen’ test on ‘spacer’ (lost circulation materials) intended to avoid contamination of the oil base drill mud, performing and interpreting positive and negative pressure tests, transferring drilling mud between tanks, and working with BP and Transocean ‘guests’ who were onboard to observe operations and congratulate the Transocean crew for their splendid safety record. Available information and testimony indicates that multiple sensors and

alarms that had been installed on the Deepwater Horizon to provide data on important parts of the operations were not 'coordinated,' 'displayed,' or in some cases, such as the general alarm and a critical flow sensor for the final part of the displacement, bypassed. Direct and unambiguous information on volume of fluids going into and out of the well was not readily available. With multiple distractions and ambiguous data difficult to analyze, the crew was not able to detect, analyze, and effectively react to the developing blowout.

Analyses of past accidents repeatedly have shown the 'perils of parallel processing' at critical times and places in operations. The simultaneous oil and gas production operations and critical maintenance operations prior to the failure of the Occidental Petroleum Piper Alpha platform in the North Sea, and the simultaneous operations carried out onboard the bridge of the Exxon Valdez tanker as it was departing outside the approved shipping lane in Prince William Sound are prime examples of the perils of parallel processing. While each of these simultaneous operations can be 'safe', it is their unexpected and unmanaged interactions and distractions at critical times and places that can provide the impetus for catastrophic failures.

Conclusion: Nevertheless, kick indications were clear enough that, if observed and recognized, these warnings would have allowed the rig crew to have responded earlier.

Comment: In hindsight, it is evident that the well was in the process of 'kicking' for almost an hour before it actually blew out. Yet, no one on the rig noticed the evolution until sea water was blown to the top of the drilling derrick, followed quickly by a stream and shower of oil drilling mud, followed by gas and oil that spread across the decks of the Deepwater Horizon. Early detection of the symptoms of a potential crisis situation is critical so that more time is available to analyze and understand those symptoms, analyze alternatives for corrective action, and then implement the alternative or alternatives that can rescue the system. The available evidence indicates that those on the Deepwater Horizon that night were confident that the well was secure and that all was going just fine. They would be wrapping up this "well from hell" in a few hours, moving the rig to a new location, and going home for a much deserved break. The evidence indicates that vigilance and preparations to handle crisis had turned to complacency in the haste to wrap up the Macondo well and move on to another offshore project.

Conclusion: Once the rig crew recognized the influx, there were several options that might have prevented or delayed the explosion and/or shut in the well.

Comment: As acknowledged by the Commission investigators, once portions of the rapidly expanding gas and hydrocarbons were in the riser, it was too late to prevent the gas and hydrocarbons from reaching the drill deck. When the gas and hydrocarbons reached the drill deck, immediate activation of the emergency shut down systems for ventilation and diversion of the gas and hydrocarbons directly overboard could possibly have prevented the explosions and fires. Unfortunately, the emergency shut down on ventilation systems apparently had been put on 'inhibit mode' requiring human activation that came too late. Because the large hydrocarbon influx was not detected in earlier stages, the closing of the annular BOP may have been "too little and too late".

The decision was made on the drill floor (perhaps days or weeks before) to divert the well flow to the "poor-boy" mud gas separator that could not handle the flow pressures and volumes, and for reasons to be confirmed, the blowout preventer was not able to be effectively activated to stop the hydrocarbons coming from the bottom of the well.

Once the explosions and fires developed on the decks and in the moonpool of the Deepwater Horizon, the emergency disconnect system to allow the rig to separate the riser and upper BOP from the lower BOP could not be successfully activated. Also, if the annular had been successfully closed and had stemmed the flow from the well temporarily, it would have reopened and leaked after control signal and power were interrupted by the multiplexer cables (or reel arrangements for them) being damaged or destroyed by the fire. Once the multiplexer signals and power fluid through the rigid conduit were not available to the subsea control pods, one or the other pod should have automatically triggered closing the blind/shear rams using the stack-mounted fluid power accumulator content (Deadman function). Defects in both pods prevented that from happening. The cascade of failures of the multiple emergency systems played major roles in the evolution of this disaster.

Conclusion: Diverting overboard might have prevented or delayed the explosion. Triggering the EDS (Emergency Disconnect System) prior to the explosion might have shut in the well and limited the impact of any explosion and/or blowout.

Comment: Immediate diversion overboard of the incoming expanding gas and hydrocarbons might have prevented or delayed the explosion. The low capacity mud – gas separator should not have been left open. However, based on the available testimony and evidence, due to the very rapid developments, sufficient time was not available for the crew to detect and analyze what was happening and take effective action. This 'surprise factor' could have been mitigated by much earlier detection of the hydrocarbon inflow and through the use of an improved overboard diversion system and refinement of protocols (pre-selection of options) for its use.

Conclusion: Technical conclusions regarding (the) BOP (Blowout Preventer) should await results of forensic BOP examination and testing.

Comment: Available evidence and testimony indicates there were a wide variety of maintenance and modification concerns associated with the BOP. These included leaking hydraulic connections, non-functional battery packs needed to activate the blind shear BOP, 're-plumbing' of the BOP components, and overdue inspections and certifications. Review of the available test and analysis background pertaining to the reliability of the specific make and model of BOP on the Deepwater Horizon clearly shows that the industry and government had major concerns for the reliability of this 'generation' of BOP.

Conclusion: No evidence at this time to suggest that there was a conscious decision to sacrifice safety concerns to save money.

Comment: Analysis of the available evidence indicates that when given the opportunity to save time and money – and make money – tradeoffs were made for the certain thing – production – because there were perceived to be no downsides associated with the uncertain thing – failure caused by the lack of sufficient protection. Thus, as a result of a cascade of deeply flawed failure and signal analysis, decision-making, communication, and organizational - managerial processes, safety was compromised to the point that the blowout occurred with catastrophic effects.

Time and cost pressures are an inherent part of this type of operation. Operations of this type cost $1 to $1.25 million per day – nearly $1,000 per minute. Income from the operations also provides important pressures. A well like Macondo can produce 50,000 barrels of oil per day – or more. This production has a total value (upstream and downstream) that approaches $10 millions per day or about $7,000 per minute.

The DHSG does not conclude those who worked on the Deepwater Horizon Macondo well project made conscious 'well informed' decisions to trade safety for money. The DHSG analyses of the available evidence indicates they were trading something that was in their estimation unlikely for something that was sure. They were trading sure savings in time and money – and perhaps quicker returns on investments - for the very unlikely possibility of a blowout and its unimagined severe consequences. The risks were erroneously judged to be insignificant. Thus, erroneous tradeoffs between risks (safety) and costs were developed.

The available evidence indicates this crew, the onshore support staffs, and the regulatory agency staffs had never experienced a major accident such as unfolded on the Deepwater Horizon. This failure was beyond their experience – a "failure of imagination. "

The Macondo well permitting documentation clearly shows that both BP and the MMS believed the likelihood of a catastrophic blowout were not significant. Blowout prevention plans were not required (waived). Procedures, processes, and equipment for containment and cleanup of the 'worst case' blowout were deemed to be readily available and would prevent significant negative environmental impacts.

There was significant experience to bolster this over confidence in success. This very complex system (managers, men, and machines) had just completed a world record setting operation to the west of the Macondo well – the Tiber well. The Tiber well was drilled to 35,000 feet below the drill deck in more than 4,000 feet of water. The Tiber well led to discovery of more than 3 billion barrels of hydrocarbon reserves. This system had completed 7 years without a reportable - recordable lost time accident. This system was confident in its abilities to cope with the challenges posed by the Macondo well – whose risks were judged to be 'insignificant.'

Available evidence and testimony indicates there were multiple (10 or more) major decisions and subsequent actions that developed in the days before the blowout that in hindsight (hindsight does not equal foresight) led to the blowout. There were conscious deliberations about each of the primary decisions and action sequences – on the rig and 'on the beach' (the office staffs). The well permitting documentation contains many detailed flow charts and decision points that were used in parts of this operation. In each case, these deliberations addressed the likelihoods and consequences of failure (a blowout) – implicitly or explicitly.

This system also had proactive, interactive, and reactive risk management processes that were in place and implemented (well or poorly) before the blowout. The proactive processes included provisions for inspections – maintenance – and repairs of critical pieces of hardware such as the blowout preventer. Interactive processes included formal management of change processes. There were interactive quality assurance and control procedures to address risks during operations such as the procedures for negative pressure testing and setting a barrier 3,300 feet below the seafloor. There were procedures, processes, and hardware for reactive risk assessment and management – automatic shut in systems, blowout preventers, emergency disconnect systems, emergency evacuation systems, and environmental protection systems. This system had a substantial suite of risk assessment and management processes intended to enhance prevention, interception, and reaction to a catastrophic blowout.

When each of the primary decisions and subsequent actions concerning the production well design and temporary abandonment were developed, the available evidence indicates the risk assessments were that there were no significant likelihoods or consequences associated with failure. The available evidence does not indicate that any one person or group was keeping tabs on the accumulation of risk that accompanied the individual decisions and subsequent actions or inactions Thus, apparently it was concluded by those involved in this operation (BP, MMS, Transocean, Halliburton, etc.) that there were no significant challenges to 'safety'. A realistic, rigorous Risk Analysis and Management (RAM) process and Management of Change (MOC) process (for changing modes from drilling to completion) appears not to have been performed. The result was a serious compromise of process safety.

However, those involved could easily understand the potential savings in time and money associated with expedited 'efficient' operations. Also, they could easily understand this project was seriously behind schedule (more than 50 days) and over budget (approaching $100 millions). There were significant incentives to 'wrap this job up' as quickly as possible. In addition, there were significant incentives to get this productive well on stream as quickly as possible – the 'last days' decisions and actions to complete the permitted exploratory well as a production well.

The available documentation does not provide any references to guidelines on how their risk assessments were developed and validated. In the majority of cases, judgments of the likelihoods and consequences of failures (e.g. blowout) appear to have been based on unsubstantiated 'feelings.' The available documentation does not indicate that any of the participants had significant formal training or qualifications in risk assessment and management of complex systems. Experience has adequately demonstrated that a few hours of training with a 'risk matrix' (plot of likelihoods versus consequences) does not qualify people to perform risk assessments of complex systems. The power of this extensive branch of technology is critically dependent on the knowledge, qualifications, training, experience, and motivations of the people who use it.

The assessments'findings that there were no significant risks is not surprising. The likelihoods and consequences were incorrectly judged by those involved not to be significant. Deeply flawed and deficient risk assessment and management processes were in place and were being used. Protective barriers were in place and were incorrectly thought to be sufficient and functional. The failures that developed before, during, and after the Macondo well project clearly show these risk assessment and management processes – barriers - were deeply deficient and pervasively flawed. Important things that were supposed to have been done correctly were either not done or were not done correctly. When the system was 'tested' before, during, and after the blowout, it performed miserably.

As described by Exxon-Mobil CEO Rex Tillerson in response to questions before the National Commission, an organization's safety culture takes time (several decades) to develop and has to be grown from within – you can't buy it or import it – it has to be nurtured from within the organization. Exxon-Mobil has been at it now for more than twenty years, after learning the hard way and paying for its complacency and risk management failures that led to the Valdez spill. Since that time, Exxon-Mobil has turned the corner and introduced many positive innovations to improve safety culture, such as their Operations Integrity Management System (OIMS), introduced in 1992 as an integral part of their overall safety management system.

In contrast, at the time of the Macondo blowout, BP's corporate culture remained one that was embedded in risk-taking and cost-cutting – it was like that in 2005 (Texas City), in 2006 (Alaska North Slope Spill), and in 2010 ("The Spill").[8] Perhaps there is no clear-cut "evidence" that someone in BP or in the other organizations in the Macondo well project made a conscious decision to put costs before safety; nevertheless, that misses the point. It is the underlying "unconscious mind" that governs the actions of an organization and its personnel. Cultural influences that permeate an organization and an industry and manifest in actions that can either promote and nurture a high reliability organization with high reliability systems, or actions reflective of complacency, excessive risk-taking, and a loss of situational awareness.

MANAGERIAL CONCLUSIONS

Conclusion: Individuals should be trained to repeatedly question data, raise concerns, and double-check assumptions.

Comment: Significant resources have been devoted to learning about training people to perform complex operations. One of the key insights developed from this work is effective training requires effective selection of personnel who will perform specific types of operations. The selection process is intended to identify individuals who have the talents and abilities required to work with a particular system – the *Right Stuff*.[9] Training can then be used to help amplify the required talents and abilities to develop the needed capabilities and competencies. Training needs to address normal, abnormal, and unbelievable situations and developments. Excellent guidelines that address the challenges associated with selection and training of personnel to operate critical systems have been developed for high reliability systems such as commercial nuclear power generation and commercial aviation.

[8] W.E. Gale, Jr., "Perspectives on Changing Safety Culture and Managing Risk," R.G. Bea, "Understanding the Macondo Well Failures," K. Roberts, "After the Dust Settles," E. Roe and P. Schulman, "A High Reliability Management Perspective on the Deepwater Horizon Spill, Including Research Implications," DHSG Working Papers, 2010.
[9] R. G. Bea, "Managing Rapidly Developing Crises – Real-Time Prevention of Failures," DHSG Working Paper, 2010.

Experience with complex systems has shown these systems literally live or die based on the assumptions (explicit, implicit) that are made about a system during its lifetime. If the assumptions are valid, the ensuing developments (analyses, actions) if properly performed can produce desirable results. If the assumptions are not valid, then even if the analyses and actions are properly performed, undesirable results (failures) can be expected. Formal structured processes (internal, external) have been developed to validate assumptions and the analytical processes based on the assumptions. These processes should be included in future developments associated with high hazard exploratory drilling and production system operations.

It is important that management understands the overall risks involved in drilling a deepwater well and that they understand what it takes to make a robust deepwater well design.[10] A competent team has the know-how to deal with the tasks in hand, i.e., the team members possess certain measurable skills, sound education, good intuitive judgment, experience, an ability to apply related knowledge to solve problems and a responsible attitude. Stakeholders will trust a professional team based on competence proven on previous track records of the individuals.

The competency of a company's drilling team, whether the team has the right persons for the job or previous success has made them complacent, "making short cuts", should be questioned in case of incidents occurring. Equally so, the competency of those who verify the well design and those who approve the non-conformances or changes should be questioned.

The composition, competency and integration of a team have a significant effect on its success. When management assigns tasks to individuals they assume that the person has the competency and will have "hands on" the work to be carried out. In the oil and gas industry there are long traditions of how a drilling team is composed and there isn't much difference from one oil company to another in how the work is organized. However, risk assessment, planning, and contractual issues may vary considerably and so the performance.

When a drilling team is faced with a situation they didn't contemplate and there are no operating procedures for handling it, then full management attention should be required. If critical, the top management of the organization should be informed. The decision whether to stop a risky operation or not should be taken by the most competent personnel, i.e., a person or persons who have experienced and handled similar situations. Top management or the regulatory body will normally not have the competency required to handle an unexpected operational issue, but they can contribute, ensuring that best resources and information are made available. The team's ability to handle unexpected situations is very much dependent on how it has been trained and its ability to communicate incidents or non-conformances in real time to its stakeholders.

[10] Y. Duesund and O.T. Gudmestad, "Deepwater Well Design, Competency – Management of Risks," DHSG Working Paper, 2010.

Conclusion: Greater attention should be paid to the magnitude of consequences of all anomalies, even seemingly minor anomalies.

Comment: Attention is a vital and perishable human resource. Choosing what to pay attention to and what not to pay attention to during the performance of complex tasks requires the skills of discrimination. This is particularly difficult when the signals associated with anomalies are weak in a 'strong noise environment.'

Slowly evolving developments leading to crises frequently are difficult to detect because signals of evolving degradations are drowned out by the noise of normal daily operations. We loose our ability to expect the unexpected frequently losing situational awareness. Values, beliefs, and feelings trump knowledge, logic and good sense and we fail to take appropriate action. Slowly developing crises, if properly detected and evaluated, provide time to develop optimized solutions, experimentation, and correction.

Rapidly evolving developments leading to crises frequently are difficult to manage because of surprise factors – they destroy beliefs - and time pressures that can lead to cognitive lock-up – tunnel vision. In such crises, the challenge is to survive – quickly find and implement a solution that works.

The problems associated with correct diagnosis of clues also pose major challenges in managing crises – correctly connecting the 'dots' (clues) that tell us what causes or problems are causing escalation of the crisis. Flawed mental models (wrong, incomplete), defensive behavior (actions to avoid embarrassment, injury and loss), muddled goals (contradictory), uncertainties, repair service behavior (treating symptoms not causes) and denying unwelcome realities lead to failure to properly connect the dots.

Conclusion: Individual risk factors cannot be considered in isolation but as an overall matrix. Personnel can not ignore anomalies after believing they have addressed them.

Comment: The available evidence does indicate that risk assessments associated with completion and temporary abandonment of the Macondo well were made separately – there was no 'risk memory.' This type of challenge is one of the key reasons for requirements of disciplined formal Management of Change procedures and processes, Safety Cases, and Process Safety analyses. While each step in a proposed process can be judged to be 'safe', due to the uncertainties associated with the conditions and analyses, the accumulation of risk in the process can prove to be fatal.

The need for continuous vigilance during performance of critical processes is an important part of risk assessment and management (RAM) and Management of Change (MOC) processes to maintain the reliability of complex systems operating in hazardous environments. Interactive RAM processes performed during the time activities are performed take many forms – such as Quality Assurance and Control, Management of Change, and Management of Crises. Early detection of anomalies that can be indicative of failure and risk escalation can provide more time for analyses of the anomalies, mobilization of resources, and implementation of strategies to return a system to a reliable state. Similarly, after the system has been returned to a reliable state, the process of 'observe, orient, decide, act' (OODA)[9] must be continued to confirm that a reliable state has been achieved and is being maintained. The Macondo well pre-failure experience clearly shows an important need to develop more effective interactive RAM processes and systems for all parts of these high hazard systems including concept development, design, construction, operation, and maintenance. Development and implementation of effective systems to facilitate RAM of rapidly (surprise) and slowly (sneaker) developing crises should be given high priority.

Conclusion: There should be greater focus on procedures and training in how to respond to low-frequency, high-risk events. "How do you know it's bad enough to act fast?"

Comment: Crises are complex frequently unforgiving unraveling of the order we try to give the world. Crises destroy beliefs, challenge our expectations and test the power to reason. Crises show weaknesses and strengths that would not otherwise be apparent. Study of recent crises that turned into failures clearly indicates that many are incubated by 'pushing the envelope' frequently indicated by the business mantra - better, faster, cheaper – doing more with less. Relentless focus on productivity can lead to increases in crisis vulnerability. This focus frequently shows up as departures from safe operating procedures to save time, money and energy. Many times, these departures act to trigger the sequence of events that escalate to an accident or failure.

Another major contributor to many current failures to deal successfully with crises that challenge complex systems is loss of core competencies, particularly those of high quality science, engineering, operations and management. Often the loss of core competencies develops in response to a business mantra: down-sizing and out-sourcing. The enterprise wants to create lean and mean organizations and that can be good as long as it does not lead to anorexic hemophiliac organizations that bleed to death when scratched. Organizations are tempted to think they can get the expensive expertise needed by outsourcing and miss understanding that the outsource organization does not have the same fundamental goals and objectives as the buyer. It is evident that the organization that outsources must have expertise that equals or exceeds that of the outsourcer. One can not adequately manage what one does not understand or can not do.

The study of near misses and accidents shows that vast majority of events that triggered a crisis are malfunctions of commission: People perform an action on purpose and it either comes out wrong or is performed incorrectly. Even more interesting, most factors that contribute to triggering events are organizational malfunctions that grow out of poor communications and productivity-at-any-cost cultures. At the same time, the vast majority of factors that rescue a crisis from failure involve organizational interactions. In other words, some organizations know how to snatch victory from defeat by providing the right stuff in the right places at the right times and ways. These organizations are constant alert for the early warning signs of crises. They select personnel and develop highly functional teams based on demonstrated capabilities and talents. They provide hardware support to not only provide early warnings, but also protect people physically and mentally and to avoid overloading and distractions.

These organizations have a strong, top-down, strategic commitment to "quality first." They demonstrate real, long-term care, concern and action, not just top-down but bottom-up. They create norms, rules, and procedures to remove conflicts between quality and production or service; promote continuous improvement; and manage crises. They do not take the health of their system for granted. They reflect, audit, critique, and listen to feedback on the health of both their system and their people.[11] And they practice timely, effective, thorough, and honest communications that effectively bind the individuals, teams, and organization together.

The best organizations prepare by creating systems and people robust enough to tolerate damage and defects and resilient enough to bounce back from trauma. Such systems embody four important elements: 1) appropriate configurations - they put the right stuff in the right places at the right times, 2) excess capacity - they can carry excessive demands when one or more elements become overloaded, 3) ductility - they stretch and deform with out breaking or loosing capacity; and 4) appropriate association - they morph to fit the situation, turning independent or high associative when required.

Effective crisis management systems focuses on providing people and system supports that promote protection (safety) and reliability. People support is focused on selecting, training, organizing, leading, and managing the right stuff - assuring that the right stuff is in the right amounts and places at the right times and ways. System support is focused on providing serviceable, safe, compatible and durable assemblies of hardware and humanware that are robust, resilient, and sustainable. Strategies that reduce the likelihoods of malfunctions, increase their detection and remediation, and reduce the effects of malfunctions are employed in a continuous process to improve protection and reliability – and maintain productivity.

Selection and training of people to enhance their abilities to successfully address rapidly developing crises is of critical importance. Training consists of much more than developing procedure manuals and guidelines. Prototype hardware and computer simulators that can approximate realistic crisis conditions can provide important skill building experiences. Realistic drills can also provide valuable learning experiences. Much can be learned from communities that must be constantly prepared to deal with rapidly developing crises such as emergency medicine, military operations, fire fighting, commercial nuclear power generation, and commercial aviation.

Communities that succeed in crisis management practice and drill to become near perfect.[9] That starts with communication – effective, timely, understandable – with encouragement of feedback. Crisis managers must learn to clearly explain not just goals, but why they do things so people can work independently and creatively and still move in the right direction. Team members learn to subordinate their personal prominence to achieving successful management of crises. They work within a fluid organization where leadership develops and migrates so the team can do things otherwise beyond their reach. Through experiences and practice, development and maintenance of trust is critical.

[11] E. Roe and P. Schulman, “A High Reliability Management Perspective on the Deepwater Horizon Spill, Including Research Implications,” “O.T. Gudmestad and M. Tiffany, “Issue Management - Treatment of Bad News”, DHSG Working Papers, 2010.