Sec. 999 Ultra-Deepwater Detailed Project Info

Field Type

Research Area: Low Permeability Reservoir

Project Title: **1701 – Improved Recovery**
Performer: Knowledge Reservoir, LLC

Project Abstract
This project is titled Development of a Research Report and Characterization Database of Deepwater and Ultra-Deepwater Assets in the Gulf of Mexico, including Technical Focus Direction, Incentives, Needs Assessment Analysis and Concepts Identification for Improved Recovery Techniques. The project will be led and directed by Knowledge Reservoir LLC, with primary project participants Louisiana State University, Anadarko Petroleum Corporation. Additional participants are Schlumberger, Core Laboratories and CMG.

Steven Knabe, Vice President, Production, Drilling & Completions for KR will be Project Director and the Principal Investigators will be Dandina N. Rao, Ph.D., P.Eng. Emmett C. Wells Jr. Distinguished Professor; Associate Professor, Craft & Hawkins Department of Petroleum Engineering, LSU and Frank H Lim, Senior Reservoir Engineering IOR Advisor, APC.

The project will identify improved recovery opportunities in the early stages of field development planning, such that facility and well designs can be optimized to take advantage of those opportunities. Additionally, opportunities for improved recovery in producing fields will be assessed, as will current and near-future technologies for improved recovery. The project will include characterization of deepwater and ultra-deepwater reservoir assets and compile and categorize key causes of trapped and remaining hydrocarbons in such reservoirs. The prioritization of technology gaps in improved recovery methods will also be addressed as specifically relate to deepwater and ultra-deepwater reservoirs, with the aim of identifying leading concepts for future research, investment, development, testing and deployment /application.

The project will utilize current IOR/EOR evaluation work by Anadarko and its partners on the K2 Field to jumpstart closing the technology gaps that have prevented application of an EOR process in deepwater GOM. Advanced experimental fluid and core studies are being conducted to improve understanding of reservoir process mechanisms for water-based and gas-based injection processes determined to be the most feasible injectants for deepwater reservoir conditions. A comprehensive description of the K2 EOR evaluation and initial fluid studies work is documented in OTC paper 19624 to be presented at the May 2008 Offshore Technology Conference in Houston, Texas.

State-of-the-art and unique measurement techniques currently in place at LSU will be upgraded to characterize DW/UDW reservoir fluid-fluid and rock-fluids interactions at actual reservoir conditions of pressures and temperatures. This will aid in making key decisions on the IOR processes suitable for DW/UDW applications. A thorough and comprehensive review of IOR/EOR techniques and experiences, both on- and offshore, will be conducted.

Project results will be captured in a knowledge base to facilitate effective technology transfer. The primary outcomes of the project will be advancement of understanding of improved recovery techniques, provision of a foundation for future development, testing and deployment phases of new technology and methodology, ultimately leading to the recovery of more resources from deepwater and ultra-deepwater assets.

Research Area: High Viscosity Oil

Project Title**: 1201 – Wax Control**
Performer: *University of Utah*

Project Abstract

Wax precipitation in flow lines is a serious problem. Unique challenges are associated with transporting fluids through long subsea pipelines. One way of preventing wax precipitation in long subsea lines is to insulate them – an expensive solution. One idea that has been tested recently, but not been implemented commercially, is cold flow. The idea is to use a non-heated, uninsulated pipeline to transport oil-water mixtures in cold, subsea environments where both hydrates and waxes are likely to form. The concept in cold flow is to create slurry of hydrate and/or wax particles and transport the oil-water mixture in the presence of this slurry. The seed particles in the slurry act as nucleation sites and prevent or minimize further wax deposition.

A number of other wax control technologies have been proposed, some of which are being commercially used. These include mechanical methods such as pigging, chemical injection technologies and thermal management strategies, which focus on preventing the problem. In previous studies, no single strategy has proven to be completely effective in preventing and/or remediating the problem. There is a necessity to carefully evaluate all available technologies, and select one or two for further evaluation.

This project uses a two-phase approach to identify the most promising technologies and forwarding them for further testing toward commercial maturity. First a comprehensive literature survey will be undertaken on this subject, and all the possible options for wax control in cold-flow subsea pipelines will be considered. This review and analysis will yield two technologies for further evaluation. These technologies will be selected based on our analysis coupled with interaction and feedback from the industrial board and from RPSEA. Testing of deep-sea flow assurance technologies will require good understanding of oil and chemical characterization, properties measurement, fluid rheology (including slurry hydrodynamics) and interfacial and surface properties. The University of Utah is uniquely positioned to undertake this project because of existing facilities and knowledge and experience in all the aspects described above. Comprehensive projects on wax precipitation in the trans-Alaskan pipeline, high-pressure carbon dioxide induced asphaltene precipitation studies, fluid compatibilities with respect of asphaltenes and waxes and chemometric methods development have all been performed at the University in the last ten years. Laboratories at the University are equipped with oil and gas characterization analytical equipment (gas chromatographs, mass spectrometers, liquid chromatographs, elemental analyzers, etc.), rheometers (including constant stress and equipment necessary for slurry characterization), instrumented flow loops and laser and particle imaging velocimetry (PIV) visualization tools. The team at the University will assemble a high pressure flow loop capable of PIV and a high-pressure rheometer for Phase 2 of the project.

The team of principal investigators at the University (Deo – characterization, precipitation and flow, Magda – rheology and Mclennan – slurry transport), will be complemented by Dr. Rich Roehner, a consultant with significant experience in all aspects of wax control in pipelines. Potential benefits of the project include identification and testing of two of the most promising subsea wax control technologies for further evaluation.

Project Title: **1901 – Subsea Processing System Integration Engineering**
Performer: *General Electric*

Project Abstract
GE will develop and validate a physics-based subsea separation simulator that will be suitable for use by both the equipment suppliers and the facility engineers to predict system performance with confidence. The outcome will be a software tool capable of simulating multiphase flow subsea processing systems that will be ready for further expansion and validation in the subsequent pilot and full-scale testing phases of the project.

GE Global Research and VetcoGray, a GE Oil and Gas business, will execute the project. Mark Lusted (GE Global Research) will be the project director, Dan Friedemann (GE VetcoGray) will be the technology lead and David Anderson (GE Global Research) will be the principal investigator. This team brings unique and comprehensive capabilities to this project including:

- World-class understanding of subsea technologies
- Proven experience in experimental testing of multi-phase flow phenomena
- In-depth experience with modeling, designing and fielding subsea systems
- Broad experience with the full range dynamic simulation tools for operational performance prediction

As existing well depletion and increasing oil and gas demand drive toward production from increasingly challenging assets, Subsea Processing (SSP) at increasing depths (up to 3000m) and pressures (>300 bar) is becoming ever more important. Separation of multi-phase flow is a critical element of such SSP primarily to increase production rates and total production via supporting pumping and compression, and remedy flow assurance challenges. Despite the assertions by equipment suppliers that Compact Subsea Processing Systems are ready for deployment, operating engineers remain less certain of that readiness due to a lack of a robust simulator able to predict system performance (in particular separator performance) throughout a full range of possible operating conditions.

The objective of this project is to develop and validate a physics-based simulator capable of predicting the separator performance over the range of conditions and fluid compositions found in the Gulf of Mexico. Combining GE VetcoGray's experience with SSP and GE Global Research's experience with testing and simulation, GE will develop a hierarchical simulation model with four tiers: component model library, separator, separation system and statistical performance solver wrapper. This simulator will be validated at the component and simulator levels in an existing GE multiphase flow test loop optimized for this project and scaling rules will be developed to predict performance at full-scale size and pressures. The hierarchical structure of the resulting simulator will have the flexibility at the component- level to be expanded as better physical descriptions of components become available, and the Simulator will interface directly with existing production modeling software such as OLGA.

Ultimately, by bringing to bear the combined expertise of Global Research and

VetcoGray in the rapid fielding of technology, GE will develop a technology transfer plan with RPSEA to ensure software enhancement through beta user input and rapid, widespread acceptance of the Simulator throughout the industry.

Research Area: xHPHT

Project Title: **1401- Composite Riser for Ultra-Deepwater High Pressure Wells**

Performers: *Lincoln Composites*

Project Abstract

This proposal to develop a Composite Riser for Ultra-Deepwater High-Pressure Wells Program together with the U.S. Department of Energy and the Research Partnership to Secure Energy for America and Lincoln Composites, Inc. a member of the Hexagon Composites Group, will develop and build a cost-effective composite riser solution suitable for use in ultra-deepwater high-pressure wells where supporting the weight of an all-steel riser solution becomes problematic. Led by Project Director Donald Baldwin, whose experience in this field spans more than 22 years, Lincoln Composites will incorporate Lincoln Composites' patented structural composite/steel trap lock interface in a hybrid composite riser capable of more than a 50% weight reduction compared to all steel risers. The weight reduction possibilities of a hybrid composite/steel riser system would enable access ultra-deepwater high-pressure reservoirs that would otherwise prove cost ineffective or technically not possible by conventional all-steel means.

The objectives of Phase 1 of this project include complete Basis of Design study and analysis to determine appropriate criteria for design and analysis as well as fabrication and proof of concept testing of full-diameter, length-scaled riser joints. The primary objective during this stage of the program is to create a riser system that satisfies regulatory concerns, industry performance standards and sufficient margins of safety to eliminate apprehension at the operator level. It is the intent of this proposal to provide a deepwater solution and enable access to oil reserves previously unreachable, yet with current top-side tension capabilities. The result of Phase 1 of RPSEA DW1401 will be a solution that is ready for trial/use in the field with proven top-side TLP and SPAR technology under similar load conditions at water depths far exceeding current capabilities. Upon the conclusion of Phase 1 of this RPSEA proposal, Lincoln Composites would complete the design for a full scale trial specimen to be fabricated and deployed for use in field trial efforts.

Lincoln Composites will utilize previous experience in the hybrid riser field, state of the art finite element modeling software for hybrid composite structures as well as collaboration with industry experts in large scale design and testing methods. Stress Engineering Services will provide testing and consulting services as part of this proposal. Their contribution adds a tremendous amount of experience and understanding of field use requirements un-rivaled in the industry.

Project Title: **1403: Fatigue Performance of High Strength Riser Materials Subjected to Sour Environments**

Performer: *Southwest Research Institute*

Project Abstract

Objectives:

New offshore reserves have exhausted the design margin available with conventional materials requiring a new generation of high strength, corrosion resistant alloys suitable for sour conditions. Although some of these materials likely already exist, the testing has not been performed to identify them. Given this, the overall objective of this program is to develop fatigue performance data for high strength materials for deepwater, high pressure, high temperature and sour/corrosive reservoir fluid risers. The focus of this program is to explore several different materials and systems (titanium, steel, forgings and nickel alloys) and determine which of these various materials exhibits the best properties. Both fatigue crack initiation (S-N) and fatigue crack growth (FCG) behavior will be assessed during this program in a variety of different environmental conditions.

Description and Methods:

This program is a material screening program designed to quantify and understand performance of high strength alloys in primarily sour conditions. Fatigue testing (both stress-life and fatigue crack growth) will be performed on candidate steel, titanium and nickel-rich alloys. A variety of test environments will be utilized during testing including: lab air, seawater, seawater with cathodic protection, sour brine and sour brine with InsulGel on the specimen (InsulGel is a heat transfer insulation). Existing facilities at SwRI will be used for testing in the highly aggressive environments. Some limited fatigue testing examining the impact of test duration (frequency effects) and variable amplitude loading will also be performed on selected materials to assist in optimizing test conditions for replicating in-service behavior. In addition to the fatigue testing, the fracture properties will also be assessed by measuring tensile properties as well as fracture toughness (JIc-based). The total program duration is 15 months with over 200 tests planned.

Impact:

Upon completion of this program, the most promising materials for the next generation of reserve developments will be identified. Once identified, these candidate materials can be further developed to enhance their properties for the given design considerations. These materials will also be subject to further investigation for different properties and behavior during subsequent phases of this program.

Crosscutting Technology Challenges

Research Area: Environmental

Project Title: **1301 - Improvements to Deepwater Subsea Measurements**
Performer: *Letton- Hall Group*

Project Abstract
The project *Improvements to Deepwater Subsea Measurement* consists of six distinct tasks as described below. For each task are shown the name of the task, its objectives, a description of the project, its potential benefits/impact, and the major participants.

Deepwater Subsea Sampling
The goal of this task is to develop hardware and procedures that allow an ROV-based mechanism to collect a sample at the wellhead, and to document the work so that standards for the pieces can be adopted. Prototypes will be built, and then tested at the surface and in simulation (underwater) tanks. Success will greatly aid reservoir understanding, as well as improve well head metering accuracy, resulting in better recovery of oil and gas. Major participants will be the LHG and Oceaneering International (OII)

ROV-Assisted Subsea Measurement
The goal of this task is to develop and prove methods for conveying a clamp-on meter to the sea floor by ROV, and there taking measurements that indicate flow rate. The pieces will be documented as drafts of future standards. Meters/sensors will be marinized for prototype demonstration in surface flow loops and in simulation tanks. If the measurements prove useful, flow rates from individual wells will be known more accurately, thus reducing risk to both producers and to the US government and improving reservoir recovery. Major participants will be the LHG and Oceaneering International (OII).

HP/HT Qualification
The goal here is to make available for extreme (high-pressure, high temperature) subsea production the sensors needed, which due to small numbers might not be developed through commercial-only forces. The key element needed is a combination pressure-differential pressure (P-DP) sensor that can be used at pressures and temperatures that are far higher than current standard conditions. The benefit from this work is the ability to measure flow in these hugely important HP/HT fields, thus permitting accurate revenue/royalty allocation and improved recovery. LHG and Axept are the participants in the development.

Evaluation of Flow Modeling
Meters that use collections of pressure and temperature sensor data in lieu of a physical multiphase flow meter are *Virtual Flow Meters* (VFM). A thorough test of commercial VFMs is the goal of this task, with a report that rigorously evaluates them. The desired outcome is greater use of VFM in situations where they are appropriate, e.g. backup of primary physical meters on wells. The main participant is Multiphase Systems Integration (MSI).

Meter Fouling Effects
The goal of this task is a greater understanding of the effects on meters of principal kinds of fouling – scale, wax, and erosion. Two kinds of meters will be tested at various stages of fouling

in various simulated production (multiphase) conditions. The benefits from this knowledge are models which predict the effects on meter readings of common fouling mechanisms and thereby improve accuracy.

Metering System Uncertainty

The intent of this task is to develop a “tool” that will give users the ability to calculate the uncertainty in measurement at the subsea meter, at the separator topside, and at other points in between. Merging carefully developed models of multiphase flow with separator and meter models in a unified system will result in a useful tool for the production engineer. The primary participants in the work will be MSI and the LHG.

Five of the six technical tasks are due for completion within 24 months from start. ROV-Assisted Measurement has a 30-month duration, as will a seventh task, *Technology Transfer*.

Project Title: **1401- Composite Riser for Ultra-Deepwater High Pressure Wells**

Performers: *Lincoln Composites*

Project Abstract

This proposal to develop a Composite Riser for Ultra-Deepwater High-Pressure Wells Program together with the U.S. Department of Energy and the Research Partnership to Secure Energy for America and Lincoln Composites, Inc. a member of the Hexagon Composites Group, will develop and build a cost-effective composite riser solution suitable for use in ultra-deepwater high-pressure wells where supporting the weight of an all-steel riser solution becomes problematic. Led by Project Director Donald Baldwin, whose experience in this field spans more than 22 years, Lincoln Composites will incorporate Lincoln Composites' patented structural composite/steel trap lock interface in a hybrid composite riser capable of more than a 50% weight reduction compared to all steel risers. The weight reduction possibilities of a hybrid composite/steel riser system would enable access ultra-deepwater high-pressure reservoirs that would otherwise prove cost ineffective or technically not possible by conventional all-steel means.

The objectives of Phase 1 of this project include complete Basis of Design study and analysis to determine appropriate criteria for design and analysis as well as fabrication and proof of concept testing of full-diameter, length-scaled riser joints. The primary objective during this stage of the program is to create a riser system that satisfies regulatory concerns, industry performance standards and sufficient margins of safety to eliminate apprehension at the operator level. It is the intent of this proposal to provide a deepwater solution and enable access to oil reserves previously unreachable, yet with current top-side tension capabilities. The result of Phase 1 of RPSEA DW1401 will be a solution that is ready for trial/use in the field with proven top-side TLP and SPAR technology under similar load conditions at water depths far exceeding current capabilities. Upon the conclusion of Phase 1 of this RPSEA proposal, Lincoln Composites would complete the design for a full scale trial specimen to be fabricated and deployed for use in field trial efforts.

Lincoln Composites will utilize previous experience in the hybrid riser field, state of the art finite element modeling software for hybrid composite structures as well as collaboration with industry experts in large scale design and testing methods. Stress Engineering Services will provide testing and consulting services as part of this proposal. Their contribution adds a tremendous amount of experience and understanding of field use requirements un-rivaled in the industry.

Project Title: **1801 – Effect of Global Warming on Hurricane Activity in the North Atlantic**

Performer: National Center for Atmospheric Research

Project Abstract

Project Overview: The study will conduct an assessment of potential impacts of global warming on North Atlantic hurricane activity with a focus on the Gulf of Mexico. The large-scale component will be provided by existing global climate simulations from the NCAR CCSM3 archive of simulations undertaken for the IPCC. This is one of the best global climate models and by using the IPCC archive we are assured of a simulation set that has been thoroughly and critically examined by the scientific community and has well understood characteristics. These global simulations are of too course a resolution for assessing hurricane activity, so we plan to nest the NCAR Advanced Research Weather
Research and Forecasting (ARW) model in its Nested Regional Climate Model (NRCM) mode into the
CCSM3 and conduct a set of high resolution downscaling simulations for current and future climate. This work will be conducted in collaboration with an ongoing NCAR downscaling program for high-impact weather, thus substantially increasing the available resources and enabling efficiencies through combination of the efforts. The hurricane results will be used to advise RPSEA on how much the hurricane intensity and frequency is likely to change in the Gulf of Mexico over approximately the next 50 years. All data will also be archived and made available for further studies on hurricane responses to climate variability and change.

Project Impacts: Since the disastrous 2004 and 2005 hurricane seasons, there has been a considerable amount of debate on whether we are currently seeing impacts of global warming and on what the likely future changes will be. The debate has at times been acrimonious and the lack of hard evidence has left open opportunities for misinterpretation and justification of pre-existing beliefs. In addition to the immediate findings that will be relayed as a direct result of this study, NCAR will, with RPSEA's approval, archive all simulations in a form that will be readily accessible to other researchers, thus enabling a wider group to investigate this important issue. We also envisage using the these initial simulations as a basis for future simulations at higher resolution and with improved physics as computing systems and our overall knowledge improves.

Project Title: **1901 – Subsea Processing System Integration Engineering**
Performer: *General Electric*

Project Abstract
GE will develop and validate a physics-based subsea separation simulator that will be suitable for use by both the equipment suppliers and the facility engineers to predict system performance with confidence. The outcome will be a software tool capable of simulating multiphase flow subsea processing systems that will be ready for further expansion and validation in the subsequent pilot and full-scale testing phases of the project.

GE Global Research and VetcoGray, a GE Oil and Gas business, will execute the project. Mark Lusted (GE Global Research) will be the project director, Dan Friedemann (GE VetcoGray) will be the technology lead and David Anderson (GE Global Research) will be the principal investigator. This team brings unique and comprehensive capabilities to this project including:

- World-class understanding of subsea technologies
- Proven experience in experimental testing of multi-phase flow phenomena
- In-depth experience with modeling, designing and fielding subsea systems
- Broad experience with the full range dynamic simulation tools for operational performance prediction

As existing well depletion and increasing oil and gas demand drive toward production from increasingly challenging assets, Subsea Processing (SSP) at increasing depths (up to 3000m) and pressures (>300 bar) is becoming ever more important. Separation of multi-phase flow is a critical element of such SSP primarily to increase production rates and total production via supporting pumping and compression, and remedy flow assurance challenges. Despite the assertions by equipment suppliers that Compact Subsea Processing Systems are ready for deployment, operating engineers remain less certain of that readiness due to a lack of a robust simulator able to predict system performance (in particular separator performance) throughout a full range of possible operating conditions.

The objective of this project is to develop and validate a physics-based simulator capable of predicting the separator performance over the range of conditions and fluid compositions found in the Gulf of Mexico. Combining GE VetcoGray's experience with SSP and GE Global Research's experience with testing and simulation, GE will develop a hierarchical simulation model with four tiers: component model library, separator, separation system and statistical performance solver wrapper. This simulator will be validated at the component and simulator levels in an existing GE multiphase flow test loop optimized for this project and scaling rules will be developed to predict performance at full-scale size and pressures. The hierarchical structure of the resulting simulator will have the flexibility at the component- level to be expanded as better physical descriptions of components become available, and the Simulator will interface directly with existing production modeling software such as OLGA.

Ultimately, by bringing to bear the combined expertise of Global Research and

VetcoGray in the rapid fielding of technology, GE will develop a technology transfer plan with RPSEA to ensure software enhancement through beta user input and rapid, widespread acceptance of the Simulator throughout the industry.

Project Title: **1902 - Deep Sea Hybrid Power Systems - Phase 1**
Performer: *Houston Advanced Research Center*

Project Abstract

The Houston Advanced Research Center (HARC) will partner with Lawrence Livermore National Laboratory (LLNL), Naval Facilities Engineering Service Center, Yardney Technical Products, Shell, Chevron and GE to evaluate alternative methods for locally generating significant electrical power on the seafloor near large consumption points. Dr. Richard C. Haut from HARC will be the Principal Investigator leading the team effort with the objective of developing hybrid energy conversion and storage systems for deep ocean operations. Such power systems will be located on the oceans floor, and will be used to supply oil and gas exploration activities, as well as drilling operations required to harvest petroleum reserves.

An investment in subsea (deep-ocean) hybrid power systems is required to enable offshore oil and gas exploration and production. Advanced deep-ocean drilling operations, locally powered, will provide access to oil and gas reserves otherwise inaccessible and could decrease the air emissions associated with offshore operations. Such technology will therefore enhance the energy security of the United States. There is a strong driving force for the development of subsea capabilities on the ocean floor. Such facilities will require ample supplies of local power to operate machinery on the floor, ranging from drills to pumps and compressors.

Several potential systems for energy generation and storage technologies for unattended environmentally friendly deep-sea application, will be systematically screened during the Phase I effort of the project. Following the screening phase, work will then transition into the design and fabrication of prototypes, with both surface and sub-sea testing, Phase II. The successful technology will then be commercialized through appropriate industrial partnerships.

The proposed work will begin with the definition of systems requirements, and the establishment of quantitative and qualitative selection criteria. These criteria will be used to guide the development of subsea hybrid power system suitable for powering oil and gas equipment on the ocean floor. The existing knowledge base of high-performance energy conversion and storage systems, appropriate for underwater applications, will be used as the basis of several conceptual designs, and then those conceptual designs will be systematically screened for the best hybrid system. The data base will be archived in technical reports for use by the oil and gas industry. The selection will be performance-based, and done in a way to screen out any potential biases towards a particular technology. Following selection of the most promising generation-storage combination, a detailed conceptual design will be developed, for both a subscale prototype for initial testing and demonstration, and for a full-scale system to serve as the basis for precise economic evaluation. The prototype will then be constructed, leveraging several of the team's relationships with other organizations, and tested at operating pressure in collaboration with the Navy. With adequate high-pressure cold performance of the prototype demonstrated, the system will then be deployed to the ocean floor for additional performance testing. After satisfactory ocean-floor testing, the Procurement Programs of the various Team members will be exploited for RPSEA, to integrate those vendors required for initial deployment, with involvement of partners from the oil and gas industry.

Research Area: Flow Assurance

Project Title**: 1201 – Wax Control**
Performer: *University of Utah*

Project Abstract
Wax precipitation in flow lines is a serious problem. Unique challenges are associated with transporting fluids through long subsea pipelines. One way of preventing wax precipitation in long subsea lines is to insulate them – an expensive solution. One idea that has been tested recently, but not been implemented commercially, is cold flow. The idea is to use a non-heated, uninsulated pipeline to transport oil-water mixtures in cold, subsea environments where both hydrates and waxes are likely to form. The concept in cold flow is to create slurry of hydrate and/or wax particles and transport the oil-water mixture in the presence of this slurry. The seed particles in the slurry act as nucleation sites and prevent or minimize further wax deposition.

A number of other wax control technologies have been proposed, some of which are being commercially used. These include mechanical methods such as pigging, chemical injection technologies and thermal management strategies, which focus on preventing the problem. In previous studies, no single strategy has proven to be completely effective in preventing and/or remediating the problem. There is a necessity to carefully evaluate all available technologies, and select one or two for further evaluation.

This project uses a two-phase approach to identify the most promising technologies and forwarding them for further testing toward commercial maturity. First a comprehensive literature survey will be undertaken on this subject, and all the possible options for wax control in cold-flow subsea pipelines will be considered. This review and analysis will yield two technologies for further evaluation. These technologies will be selected based on our analysis coupled with interaction and feedback from the industrial board and from RPSEA. Testing of deep-sea flow assurance technologies will require good understanding of oil and chemical characterization, properties measurement, fluid rheology (including slurry hydrodynamics) and interfacial and surface properties. The University of Utah is uniquely positioned to undertake this project because of existing facilities and knowledge and experience in all the aspects described above. Comprehensive projects on wax precipitation in the trans-Alaskan pipeline, high-pressure carbon dioxide induced asphaltene precipitation studies, fluid compatibilities with respect of asphaltenes and waxes and chemometric methods development have all been performed at the University in the last ten years. Laboratories at the University are equipped with oil and gas characterization analytical equipment (gas chromatographs, mass spectrometers, liquid chromatographs, elemental analyzers, etc.), rheometers (including constant stress and equipment necessary for slurry characterization), instrumented flow loops and laser and particle imaging velocimetry (PIV) visualization tools. The team at the University will assemble a high pressure flow loop capable of PIV and a high-pressure rheometer for Phase 2 of the project.

The team of principal investigators at the University (Deo – characterization, precipitation and flow, Magda – rheology and Mclennan – slurry transport), will be complemented by Dr. Rich Roehner, a consultant with significant experience in all aspects of wax control in pipelines.

Potential benefits of the project include identification and testing of two of the most promising subsea wax control technologies for further evaluation.

Project Title: **1301 - Improvements to Deepwater Subsea Measurements**
Performer: *Letton- Hall Group*

Project Abstract
The project *Improvements to Deepwater Subsea Measurement* consists of six distinct tasks as described below. For each task are shown the name of the task, its objectives, a description of the project, its potential benefits/impact, and the major participants.

Deepwater Subsea Sampling
The goal of this task is to develop hardware and procedures that allow an ROV-based mechanism to collect a sample at the wellhead, and to document the work so that standards for the pieces can be adopted. Prototypes will be built, and then tested at the surface and in simulation (underwater) tanks. Success will greatly aid reservoir understanding, as well as improve well head metering accuracy, resulting in better recovery of oil and gas. Major participants will be the LHG and Oceaneering International (OII)

ROV-Assisted Subsea Measurement
The goal of this task is to develop and prove methods for conveying a clamp-on meter to the sea floor by ROV, and there taking measurements that indicate flow rate. The pieces will be documented as drafts of future standards. Meters/sensors will be marinized for prototype demonstration in surface flow loops and in simulation tanks. If the measurements prove useful, flow rates from individual wells will be known more accurately, thus reducing risk to both producers and to the US government and improving reservoir recovery. Major participants will be the LHG and Oceaneering International (OII).

HP/HT Qualification
The goal here is to make available for extreme (high-pressure, high temperature) subsea production the sensors needed, which due to small numbers might not be developed through commercial-only forces. The key element needed is a combination pressure-differential pressure (P-DP) sensor that can be used at pressures and temperatures that are far higher than current standard conditions. The benefit from this work is the ability to measure flow in these hugely important HP/HT fields, thus permitting accurate revenue/royalty allocation and improved recovery. LHG and Axept are the participants in the development.

Evaluation of Flow Modeling
Meters that use collections of pressure and temperature sensor data in lieu of a physical multiphase flow meter are *Virtual Flow Meters* (VFM). A thorough test of commercial VFMs is the goal of this task, with a report that rigorously evaluates them. The desired outcome is greater use of VFM in situations where they are appropriate, e.g. backup of primary physical meters on wells. The main participant is Multiphase Systems Integration (MSI).

Meter Fouling Effects
The goal of this task is a greater understanding of the effects on meters of principal kinds of fouling – scale, wax, and erosion. Two kinds of meters will be tested at various stages of fouling in various simulated production (multiphase) conditions. The benefits from this knowledge are models which predict the effects on meter readings of common fouling mechanisms and thereby improve accuracy.

Metering System Uncertainty

The intent of this task is to develop a “tool” that will give users the ability to calculate the uncertainty in measurement at the subsea meter, at the separator topside, and at other points in between. Merging carefully developed models of multiphase flow with separator and meter models in a unified system will result in a useful tool for the production engineer. The primary participants in the work will be MSI and the LHG.

Five of the six technical tasks are due for completion within 24 months from start. ROV-Assisted Measurement has a 30-month duration, as will a seventh task, *Technology Transfer*.

Research Area: Floating Facilities

Project Title: **1401- Composite Riser for Ultra-Deepwater High Pressure Wells**

Performers: *Lincoln Composites*

Project Abstract

This proposal to develop a Composite Riser for Ultra-Deepwater High-Pressure Wells Program together with the U.S. Department of Energy and the Research Partnership to Secure Energy for America and Lincoln Composites, Inc. a member of the Hexagon Composites Group, will develop and build a cost-effective composite riser solution suitable for use in ultra-deepwater high-pressure wells where supporting the weight of an all-steel riser solution becomes problematic. Led by Project Director Donald Baldwin, whose experience in this field spans more than 22 years, Lincoln Composites will incorporate Lincoln Composites' patented structural composite/steel trap lock interface in a hybrid composite riser capable of more than a 50% weight reduction compared to all steel risers. The weight reduction possibilities of a hybrid composite/steel riser system would enable access ultra-deepwater high-pressure reservoirs that would otherwise prove cost ineffective or technically not possible by conventional all-steel means.

The objectives of Phase 1 of this project include complete Basis of Design study and analysis to determine appropriate criteria for design and analysis as well as fabrication and proof of concept testing of full-diameter, length-scaled riser joints. The primary objective during this stage of the program is to create a riser system that satisfies regulatory concerns, industry performance standards and sufficient margins of safety to eliminate apprehension at the operator level. It is the intent of this proposal to provide a deepwater solution and enable access to oil reserves previously unreachable, yet with current top-side tension capabilities. The result of Phase 1 of RPSEA DW1401 will be a solution that is ready for trial/use in the field with proven top-side TLP and SPAR technology under similar load conditions at water depths far exceeding current capabilities. Upon the conclusion of Phase 1 of this RPSEA proposal, Lincoln Composites would complete the design for a full scale trial specimen to be fabricated and deployed for use in field trial efforts.

Lincoln Composites will utilize previous experience in the hybrid riser field, state of the art finite element modeling software for hybrid composite structures as well as collaboration with industry experts in large scale design and testing methods. Stress Engineering Services will provide testing and consulting services as part of this proposal. Their contribution adds a tremendous amount of experience and understanding of field use requirements un-rivaled in the industry.

Project Title: **1402-A: Ultra-Deepwater Dry Tree System for Drilling and Production in the GoM, Phase 1**

Performer: *FloaTEC, LLC*

Project Abstract

The RPSEA study for Phase 1 of an "Ultra-Deepwater Dry Tree System for Drilling and Production in the Gulf of Mexico" provides the opportunity to develop and evaluate competitive platform concepts that can facilitate the development of oil reserves in the U.S. Gulf waters.

FloaTEC, LLC, a 50:50 joint venture company created by J. Ray McDermott (JRM) and Keppel FELS (KFELS) to deliver deepwater floating production systems, will lead the study effort. FloaTEC intends to supplement their team by utilizing their parents' expertise in the areas of constructability in design, fabrication and installation, and by engaging specialist companies: 2H Offshore, VetcoGray, and Seadrill Americas, Inc. in the areas of riser analysis, riser and tensioner hardware, and drilling rig layout and operations, respectively.

The Project Director for FloaTEC is Mr. Jing Kuang. He will be assisted by Bala Padmanabhan, C. K. Yang, H. S. Lee and Shirish Potnis (all FloaTEC), Pranab Sarkar and Darryl Payne (J Ray McDermott), Chau Nguyen (2H), C. R. Lin (VetcoGray) as his principal investigators/lead engineers in the project team.

The main objectives of the project are to assess alternative dry tree semisubmersible concept designs for two different payload cases in accordance with the agreed basis of design, and select one hull form option for model testing and further development in Phase 2 of the RPSEA program. The intent is to investigate the feasibility of developing these platform designs and to identify any technical limits to areas where further qualification or testing will be required in the industry.

The project is divided into distinct areas of scope. The initial task is to jointly develop the basis of design for the project, followed by a sizing exercise to be able to compare all dry tree platform and riser options selected for study. A comparative assessment of the results of this task will be presented and evaluated at a workshop. The outcome of the workshop will be the selection of two dry tree hulls and riser forms (one combination for each of the two payloads considered) for further evaluation and refinement.

FloaTEC's in-house sizing tools enable the hull options to be developed on an equal basis, providing the necessary data to estimate costs to the screening level accuracy required for comparison. Similarly, the experience of the other members of project team will provide the necessary input to accurate payload development, riser and tensioner component sizing, project execution plans, and cost estimates.

The two options selected for further study will be developed to the extent necessary to ensure their feasibility in all areas, and provide sufficient detail to develop +/-30% cost estimates. A second workshop will be held to select one case to be model tested. Model testing will be performed at a reputable, experienced facility.

All results of these tasks will be assembled into a final report, and agreement will be reached on an appropriate method to transfer technology to industry.
The major outcome from the project will be an assessment of the competitiveness of a dry tree semisubmersible to the limited production platform concepts currently available for field developments in deep waters (over 6,000 ft). Any technology requiring development will be identified, allowing an accurate timeline to be established for product readiness.

Project Title: **1402-B: Ultra-Deepwater Dry Tree System for Drilling and Production in the GoM, Phase 1**

Performer: *Houston Offshore Engineering*

Project Abstract

This document describes Houston Offshore Engineering's proposal for the research and development project, "Ultra Deepwater Dry Tree System for Drilling and Production in the Gulf of Mexico." The principal technical staff proposed for the project includes Jun Zou (PhD, Manager of Naval Architecture), responsible for global configuration, global performance analysis and model test execution, and Shan Shi (PhD, Manager of Riser Systems), responsible for riser configuration, riser analysis and riser systems integration. Philip Poll (Manager of Projects) will provide overall project direction and coordination.

The primary objective of the proposed work scope is to develop a floating system concept that is suitable for drilling and production in ultra deepwater using dry trees. A second, equally important objective is to perform engineering, testing and other activities to mature the concept so that the technology is ready for implementation by oil and gas operators in the Gulf of Mexico. This commercialization objective is very important because without this step, the research and development does not provide any strategic benefit to the oil and gas industry or the United States government.

The project execution plan for this development program incorporates critical subcontracts to bring world-class expertise in the areas of hull constructability (Keppel Fels), topsides fabrication and integration (Kiewit Offshore) and model test facilities (Offshore Technology and Research Center). The combined team incorporates all the expertise necessary to ensure that the results of the research and development is a concept that will meet all functional requirements and can be built, integrated and installed using conventional facilities.

The potential impact of the project is tremendous. The benefits of dry tree development of oil and gas include increased total reserve recovery and lower cost access for well workover and maintenance. Without dry tree access, oil and gas production becomes subject to availability and cost of mobile offshore drilling units, which in the current market are difficult and expensive to contract. The existing dry tree concept for deepwater includes significant challenges and risks, including offshore integration, limited and congested wellbay area, and limited facilities for hull fabrication and transportation. A new dry tree system for ultra deepwater Gulf of Mexico has the potential to increase total reserve recovery for the United States and lower the overall cost for extracting hydrocarbons from beneath the sea floor.

Project Title: **1403: Fatigue Performance of High Strength Riser Materials Subjected to Sour Environments**

Performer: *Southwest Research Institute*

Project Abstract

Objectives:

New offshore reserves have exhausted the design margin available with conventional materials requiring a new generation of high strength, corrosion resistant alloys suitable for sour conditions. Although some of these materials likely already exist, the testing has not been performed to identify them. Given this, the overall objective of this program is to develop fatigue performance data for high strength materials for deepwater, high pressure, high temperature and sour/corrosive reservoir fluid risers. The focus of this program is to explore several different materials and systems (titanium, steel, forgings and nickel alloys) and determine which of these various materials exhibits the best properties. Both fatigue crack initiation (S-N) and fatigue crack growth (FCG) behavior will be assessed during this program in a variety of different environmental conditions.

Description and Methods:

This program is a material screening program designed to quantify and understand performance of high strength alloys in primarily sour conditions. Fatigue testing (both stress-life and fatigue crack growth) will be performed on candidate steel, titanium and nickel-rich alloys. A variety of test environments will be utilized during testing including: lab air, seawater, seawater with cathodic protection, sour brine and sour brine with InsulGel on the specimen (InsulGel is a heat transfer insulation). Existing facilities at SwRI will be used for testing in the highly aggressive environments. Some limited fatigue testing examining the impact of test duration (frequency effects) and variable amplitude loading will also be performed on selected materials to assist in optimizing test conditions for replicating in-service behavior. In addition to the fatigue testing, the fracture properties will also be assessed by measuring tensile properties as well as fracture toughness (JIc-based). The total program duration is 15 months with over 200 tests planned.

Impact:

Upon completion of this program, the most promising materials for the next generation of reserve developments will be identified. Once identified, these candidate materials can be further developed to enhance their properties for the given design considerations. These materials will also be subject to further investigation for different properties and behavior during subsequent phases of this program.

Research Area: Subsea Facilities

Project Title: **1301 - Improvements to Deepwater Subsea Measurements**
Performer: *Letton- Hall Group*

Project Abstract
The project *Improvements to Deepwater Subsea Measurement* consists of six distinct tasks as described below. For each task are shown the name of the task, its objectives, a description of the project, its potential benefits/impact, and the major participants.

Deepwater Subsea Sampling
The goal of this task is to develop hardware and procedures that allow an ROV-based mechanism to collect a sample at the wellhead, and to document the work so that standards for the pieces can be adopted. Prototypes will be built, and then tested at the surface and in simulation (underwater) tanks. Success will greatly aid reservoir understanding, as well as improve well head metering accuracy, resulting in better recovery of oil and gas. Major participants will be the LHG and Oceaneering International (OII)

ROV-Assisted Subsea Measurement
The goal of this task is to develop and prove methods for conveying a clamp-on meter to the sea floor by ROV, and there taking measurements that indicate flow rate. The pieces will be documented as drafts of future standards. Meters/sensors will be marinized for prototype demonstration in surface flow loops and in simulation tanks. If the measurements prove useful, flow rates from individual wells will be known more accurately, thus reducing risk to both producers and to the US government and improving reservoir recovery. Major participants will be the LHG and Oceaneering International (OII).

HP/HT Qualification
The goal here is to make available for extreme (high-pressure, high temperature) subsea production the sensors needed, which due to small numbers might not be developed through commercial-only forces. The key element needed is a combination pressure-differential pressure (P-DP) sensor that can be used at pressures and temperatures that are far higher than current standard conditions. The benefit from this work is the ability to measure flow in these hugely important HP/HT fields, thus permitting accurate revenue/royalty allocation and improved recovery. LHG and Axept are the participants in the development.

Evaluation of Flow Modeling
Meters that use collections of pressure and temperature sensor data in lieu of a physical multiphase flow meter are *Virtual Flow Meters* (VFM). A thorough test of commercial VFMs is the goal of this task, with a report that rigorously evaluates them. The desired outcome is greater use of VFM in situations where they are appropriate, e.g. backup of primary physical meters on wells. The main participant is Multiphase Systems Integration (MSI).

Meter Fouling Effects
The goal of this task is a greater understanding of the effects on meters of principal kinds of fouling – scale, wax, and erosion. Two kinds of meters will be tested at various stages of fouling in various simulated production (multiphase) conditions. The benefits from this knowledge are

models which predict the effects on meter readings of common fouling mechanisms and thereby improve accuracy.

Metering System Uncertainty

The intent of this task is to develop a “tool” that will give users the ability to calculate the uncertainty in measurement at the subsea meter, at the separator topside, and at other points in between. Merging carefully developed models of multiphase flow with separator and meter models in a unified system will result in a useful tool for the production engineer. The primary participants in the work will be MSI and the LHG.

Five of the six technical tasks are due for completion within 24 months from start. ROV-Assisted Measurement has a 30-month duration, as will a seventh task, *Technology Transfer*.

Project Title: **1302 - Ultra-High Conductivity Umbilicals: A Paradigm Change in Conductors Using Carbon Nanotubes**

Performer: *Technip, USA*

Project Abstract

Numerous developments have occurred that will enable the next generation of Ultra-High Conductivity Umbilicals for deep sea oil and gas production. These developments have occurred in the new field of nanotechnology and have been sparked by the exciting properties of Single Walled Carbon Nanotubes (SWCNTs). To this end, nanotubes in copper and other metals have shown promise for improved properties including electrical systems. Even lighter weight polymers with dispersed nanotubes have shown high electrical conduction with enhanced strength. Furthermore, the Armchair Quantum Wire (AQW) is a conductor cable with great promise that should be a paradigm change in the way power is distributed. The precursor to the AQW that is proposed is the Polymer Nanotube Umbilical (PNU) (conductivity that will be about four times that of copper) because it is an ultra high conductivity wire and can be delivered in the next three years. These last two systems (the AQW and PNU) provide new opportunities for electrical conducting cables that could be used for the new frontiers of oil and gas production. When considering high power requirements and long umbilical tie-back distances, there is a need for new technologies to enable power delivery to the seafloor. Carbon nanotechnology is one such new technology that could enable high power transfer for long tieback distances where lightweight and high power transfer are required. In this proposal, the opportunities from carbon nanotechnology will be described along with the development plan for a new high current density electrical wire (PNU) based on SWCNTs dispersed in a polymer binder. The new wire has the ability to be processed at long lengths with connections that could be made at numerous points along the length. This low current loss wire can be bundled into an umbilical to provide power for communication lines and to operate pumps and other subsea equipment.

Project Title: **1403: Fatigue Performance of High Strength Riser Materials Subjected to Sour Environments**

Performer: *Southwest Research Institute*

Project Abstract

Objectives:

New offshore reserves have exhausted the design margin available with conventional materials requiring a new generation of high strength, corrosion resistant alloys suitable for sour conditions. Although some of these materials likely already exist, the testing has not been performed to identify them. Given this, the overall objective of this program is to develop fatigue performance data for high strength materials for deepwater, high pressure, high temperature and sour/corrosive reservoir fluid risers. The focus of this program is to explore several different materials and systems (titanium, steel, forgings and nickel alloys) and determine which of these various materials exhibits the best properties. Both fatigue crack initiation (S-N) and fatigue crack growth (FCG) behavior will be assessed during this program in a variety of different environmental conditions.

Description and Methods:

This program is a material screening program designed to quantify and understand performance of high strength alloys in primarily sour conditions. Fatigue testing (both stress-life and fatigue crack growth) will be performed on candidate steel, titanium and nickel-rich alloys. A variety of test environments will be utilized during testing including: lab air, seawater, seawater with cathodic protection, sour brine and sour brine with InsulGel on the specimen (InsulGel is a heat transfer insulation). Existing facilities at SwRI will be used for testing in the highly aggressive environments. Some limited fatigue testing examining the impact of test duration (frequency effects) and variable amplitude loading will also be performed on selected materials to assist in optimizing test conditions for replicating in-service behavior. In addition to the fatigue testing, the fracture properties will also be assessed by measuring tensile properties as well as fracture toughness (JIc-based). The total program duration is 15 months with over 200 tests planned.

Impact:

Upon completion of this program, the most promising materials for the next generation of reserve developments will be identified. Once identified, these candidate materials can be further developed to enhance their properties for the given design considerations. These materials will also be subject to further investigation for different properties and behavior during subsequent phases of this program.

Project Title: **1901 – Subsea Processing System Integration Engineering**
Performer: *General Electric*

Project Abstract

GE will develop and validate a physics-based subsea separation simulator that will be suitable for use by both the equipment suppliers and the facility engineers to predict system performance with confidence. The outcome will be a software tool capable of simulating multiphase flow subsea processing systems that will be ready for further expansion and validation in the subsequent pilot and full-scale testing phases of the project.

GE Global Research and VetcoGray, a GE Oil and Gas business, will execute the project. Mark Lusted (GE Global Research) will be the project director, Dan Friedemann (GE VetcoGray) will be the technology lead and David Anderson (GE Global Research) will be the principal investigator. This team brings unique and comprehensive capabilities to this project including:

- World-class understanding of subsea technologies
- Proven experience in experimental testing of multi-phase flow phenomena
- In-depth experience with modeling, designing and fielding subsea systems
- Broad experience with the full range dynamic simulation tools for operational performance prediction

As existing well depletion and increasing oil and gas demand drive toward production from increasingly challenging assets, Subsea Processing (SSP) at increasing depths (up to 3000m) and pressures (>300 bar) is becoming ever more important. Separation of multi-phase flow is a critical element of such SSP primarily to increase production rates and total production via supporting pumping and compression, and remedy flow assurance challenges. Despite the assertions by equipment suppliers that Compact Subsea Processing Systems are ready for deployment, operating engineers remain less certain of that readiness due to a lack of a robust simulator able to predict system performance (in particular separator performance) throughout a full range of possible operating conditions.

The objective of this project is to develop and validate a physics-based simulator capable of predicting the separator performance over the range of conditions and fluid compositions found in the Gulf of Mexico. Combining GE VetcoGray's experience with SSP and GE Global Research's experience with testing and simulation, GE will develop a hierarchical simulation model with four tiers: component model library, separator, separation system and statistical performance solver wrapper. This simulator will be validated at the component and simulator levels in an existing GE multiphase flow test loop optimized for this project and scaling rules will be developed to predict performance at full-scale size and pressures. The hierarchical structure of the resulting simulator will have the flexibility at the component- level to be expanded as better physical descriptions of components become available, and the Simulator will interface directly with existing production modeling software such as OLGA.

Ultimately, by bringing to bear the combined expertise of Global Research and

VetcoGray in the rapid fielding of technology, GE will develop a technology transfer plan with RPSEA to ensure software enhancement through beta user input and rapid, widespread acceptance of the Simulator throughout the industry.

Project Title: **1902 - Deep Sea Hybrid Power Systems - Phase 1**
Performer: *Houston Advanced Research Center*

Project Abstract

The Houston Advanced Research Center (HARC) will partner with Lawrence Livermore National Laboratory (LLNL), Naval Facilities Engineering Service Center, Yardney Technical Products, Shell, Chevron and GE to evaluate alternative methods for locally generating significant electrical power on the seafloor near large consumption points. Dr. Richard C. Haut from HARC will be the Principal Investigator leading the team effort with the objective of developing hybrid energy conversion and storage systems for deep ocean operations. Such power systems will be located on the oceans floor, and will be used to supply oil and gas exploration activities, as well as drilling operations required to harvest petroleum reserves.

An investment in subsea (deep-ocean) hybrid power systems is required to enable offshore oil and gas exploration and production. Advanced deep-ocean drilling operations, locally powered, will provide access to oil and gas reserves otherwise inaccessible and could decrease the air emissions associated with offshore operations. Such technology will therefore enhance the energy security of the United States. There is a strong driving force for the development of subsea capabilities on the ocean floor. Such facilities will require ample supplies of local power to operate machinery on the floor, ranging from drills to pumps and compressors.

Several potential systems for energy generation and storage technologies for unattended environmentally friendly deep-sea application, will be systematically screened during the Phase I effort of the project. Following the screening phase, work will then transition into the design and fabrication of prototypes, with both surface and sub-sea testing, Phase II. The successful technology will then be commercialized through appropriate industrial partnerships.

The proposed work will begin with the definition of systems requirements, and the establishment of quantitative and qualitative selection criteria. These criteria will be used to guide the development of subsea hybrid power system suitable for powering oil and gas equipment on the ocean floor. The existing knowledge base of high-performance energy conversion and storage systems, appropriate for underwater applications, will be used as the basis of several conceptual designs, and then those conceptual designs will be systematically screened for the best hybrid system. The data base will be archived in technical reports for use by the oil and gas industry. The selection will be performance-based, and done in a way to screen out any potential biases towards a particular technology. Following selection of the most promising generation-storage combination, a detailed conceptual design will be developed, for both a subscale prototype for initial testing and demonstration, and for a full-scale system to serve as the basis for precise economic evaluation. The prototype will then be constructed, leveraging several of the team's relationships with other organizations, and tested at operating pressure in collaboration with the Navy. With adequate high-pressure cold performance of the prototype demonstrated, the system will then be deployed to the ocean floor for additional performance testing. After satisfactory ocean-floor testing, the Procurement Programs of the various Team members will be exploited for RPSEA, to integrate those vendors required for initial deployment, with involvement of partners from the oil and gas industry.

Research Area: Geo-science

Project Title: **1701 – Improved Recovery**
Performer: Knowledge Reservoir, LLC

Project Abstract
This project is titled Development of a Research Report and Characterization Database of Deepwater and Ultra-Deepwater Assets in the Gulf of Mexico, including Technical Focus Direction, Incentives, Needs Assessment Analysis and Concepts Identification for Improved Recovery Techniques. The project will be led and directed by Knowledge Reservoir LLC, with primary project participants Louisiana State University, Anadarko Petroleum Corporation. Additional participants are Schlumberger, Core Laboratories and CMG.

Steven Knabe, Vice President, Production, Drilling & Completions for KR will be Project Director and the Principal Investigators will be Dandina N. Rao, Ph.D., P.Eng. Emmett C. Wells Jr. Distinguished Professor; Associate Professor, Craft & Hawkins Department of Petroleum Engineering, LSU and Frank H Lim, Senior Reservoir Engineering IOR Advisor, APC.

The project will identify improved recovery opportunities in the early stages of field development planning, such that facility and well designs can be optimized to take advantage of those opportunities. Additionally, opportunities for improved recovery in producing fields will be assessed, as will current and near-future technologies for improved recovery. The project will include characterization of deepwater and ultra-deepwater reservoir assets and compile and categorize key causes of trapped and remaining hydrocarbons in such reservoirs. The prioritization of technology gaps in improved recovery methods will also be addressed as specifically relate to deepwater and ultra-deepwater reservoirs, with the aim of identifying leading concepts for future research, investment, development, testing and deployment /application.

The project will utilize current IOR/EOR evaluation work by Anadarko and its partners on the K2 Field to jumpstart closing the technology gaps that have prevented application of an EOR process in deepwater GOM. Advanced experimental fluid and core studies are being conducted to improve understanding of reservoir process mechanisms for water-based and gas-based injection processes determined to be the most feasible injectants for deepwater reservoir conditions. A comprehensive description of the K2 EOR evaluation and initial fluid studies work is documented in OTC paper 19624 to be presented at the May 2008 Offshore Technology Conference in Houston, Texas.

State-of-the-art and unique measurement techniques currently in place at LSU will be upgraded to characterize DW/UDW reservoir fluid-fluid and rock-fluids interactions at actual reservoir conditions of pressures and temperatures. This will aid in making key decisions on the IOR processes suitable for DW/UDW applications. A thorough and comprehensive review of IOR/EOR techniques and experiences, both on- and offshore, will be conducted.

Project results will be captured in a knowledge base to facilitate effective technology transfer. The primary outcomes of the project will be advancement of understanding of improved

recovery techniques, provision of a foundation for future development, testing and deployment phases of new technology and methodology, ultimately leading to the recovery of more resources from deepwater and ultra-deepwater assets.

Project Title: **2001 - Geophysical Modeling for Studying Acquisition and Processing Methods in the Deepwater Gulf of Mexico**
Performer: *SEG Advanced Modeling Corporation*

Project Abstract
We propose to conduct realistic simulations of geophysical data that will contribute towards the development of the next generation of imaging and acquisition approaches, lead to a higher rate of success in identifying petroleum resources in the Gulf of Mexico, and improve reservoir characterization so that production can be maximized.

- Title of Work to be performed: Geophysical Modeling for Studying Acquisition and
- Processing Methods in the Deepwater Gulf of Mexico (GOM)
- Name of the Performer: SEAM, the SEG (Society of Exploration Geophysicists) Advanced Modeling Corporation
- Project Manager: Dr. Michael Fehler
- Project title: Geophysical Modeling for Studying Acquisition and Processing Methods in the Deepwater Gulf of Mexico (GOM)
- Objectives: To contribute to the evolution of geophysical imaging technology by providing our nearly completed realistic benchmark geological model containing multiple geophysical attributes along with two synthetic seismic datasets and three synthetic nonseismic datasets that will allow industry to assess individual as well as joint geophysical acquisition and processing techniques for generating images of hydrocarbon reservoirs beneath and surrounding massive, complex salt bodies. SEAM will develop requirements for hosting and distributing these datasets for their useful lifetime, which we expect could be one or more decades.
- Description of the project including methods to be employed: SEAM will conduct its work by (a) engaging SEAM member companies in the development of acquisition plans for each geophysical simulation, (b) critical evaluation of numerical algorithms to ensure robust simulation results, (c) competitive contracting with qualified vendors to conduct the simulations, (d) implementing a detailed quality procedure to ensure the integrity of the data, (e) storing and distributing the data to potential users, and (f) communicating to a broad range of potential users in industry, government research laboratories, and academia about the work.
- Potential impact: The technical details of our proposal have been vetted by experts from our 23 participating companies and they expressed strong support for the scope of work and its extremely high value in helping them to address critical issues that limit their ability to do reliable imaging in the deepwater Gulf of Mexico. The proposed work is far-reaching; no one has done detailed 3D elastic simulations of a realistic model for the Gulf of Mexico. By striving to push beyond the technical frontier, we seek to make the greatest possible contribution to geophysical exploration. With broad industry participation and a track record of attacking difficult numerical simulation challenges, SEAM is uniquely qualified to conduct the proposed work.
- Our participating supporters include industry's leading experts in the field and are already embedded in SEAM Corporation as active participants on the Board of Directors, Management Committee, and Technical Working Groups.

Research Area: Reservoir

Project Title: **1301 - Improvements to Deepwater Subsea Measurements**
Performer: *Letton- Hall Group*

Project Abstract
The project *Improvements to Deepwater Subsea Measurement* consists of six distinct tasks as described below. For each task are shown the name of the task, its objectives, a description of the project, its potential benefits/impact, and the major participants.

Deepwater Subsea Sampling
The goal of this task is to develop hardware and procedures that allow an ROV-based mechanism to collect a sample at the wellhead, and to document the work so that standards for the pieces can be adopted. Prototypes will be built, and then tested at the surface and in simulation (underwater) tanks. Success will greatly aid reservoir understanding, as well as improve well head metering accuracy, resulting in better recovery of oil and gas. Major participants will be the LHG and Oceaneering International (OII)

ROV-Assisted Subsea Measurement
The goal of this task is to develop and prove methods for conveying a clamp-on meter to the sea floor by ROV, and there taking measurements that indicate flow rate. The pieces will be documented as drafts of future standards. Meters/sensors will be marinized for prototype demonstration in surface flow loops and in simulation tanks. If the measurements prove useful, flow rates from individual wells will be known more accurately, thus reducing risk to both producers and to the US government and improving reservoir recovery. Major participants will be the LHG and Oceaneering International (OII).

HP/HT Qualification
The goal here is to make available for extreme (high-pressure, high temperature) subsea production the sensors needed, which due to small numbers might not be developed through commercial-only forces. The key element needed is a combination pressure-differential pressure (P-DP) sensor that can be used at pressures and temperatures that are far higher than current standard conditions. The benefit from this work is the ability to measure flow in these hugely important HP/HT fields, thus permitting accurate revenue/royalty allocation and improved recovery. LHG and Axept are the participants in the development.

Evaluation of Flow Modeling
Meters that use collections of pressure and temperature sensor data in lieu of a physical multiphase flow meter are *Virtual Flow Meters* (VFM). A thorough test of commercial VFMs is the goal of this task, with a report that rigorously evaluates them. The desired outcome is greater use of VFM in situations where they are appropriate, e.g. backup of primary physical meters on wells. The main participant is Multiphase Systems Integration (MSI).

Meter Fouling Effects
The goal of this task is a greater understanding of the effects on meters of principal kinds of fouling – scale, wax, and erosion. Two kinds of meters will be tested at various stages of fouling in various simulated production (multiphase) conditions. The benefits from this knowledge are models which predict the effects on meter readings of common fouling mechanisms and thereby improve accuracy.

Metering System Uncertainty

The intent of this task is to develop a “tool” that will give users the ability to calculate the uncertainty in measurement at the subsea meter, at the separator topside, and at other points in between. Merging carefully developed models of multiphase flow with separator and meter models in a unified system will result in a useful tool for the production engineer. The primary participants in the work will be MSI and the LHG.

Five of the six technical tasks are due for completion within 24 months from start. ROV-Assisted Measurement has a 30-month duration, as will a seventh task, *Technology Transfer*.

Project Title: **1701 – Improved Recovery**
Performer: Knowledge Reservoir, LLC

Project Abstract
This project is titled Development of a Research Report and Characterization Database of Deepwater and Ultra-Deepwater Assets in the Gulf of Mexico, including Technical Focus Direction, Incentives, Needs Assessment Analysis and Concepts Identification for Improved Recovery Techniques. The project will be led and directed by Knowledge Reservoir LLC, with primary project participants Louisiana State University, Anadarko Petroleum Corporation. Additional participants are Schlumberger, Core Laboratories and CMG.

Steven Knabe, Vice President, Production, Drilling & Completions for KR will be Project Director and the Principal Investigators will be Dandina N. Rao, Ph.D., P.Eng. Emmett C. Wells Jr. Distinguished Professor; Associate Professor, Craft & Hawkins Department of Petroleum Engineering, LSU and Frank H Lim, Senior Reservoir Engineering IOR Advisor, APC.

The project will identify improved recovery opportunities in the early stages of field development planning, such that facility and well designs can be optimized to take advantage of those opportunities. Additionally, opportunities for improved recovery in producing fields will be assessed, as will current and near-future technologies for improved recovery. The project will include characterization of deepwater and ultra-deepwater reservoir assets and compile and categorize key causes of trapped and remaining hydrocarbons in such reservoirs. The prioritization of technology gaps in improved recovery methods will also be addressed as specifically relate to deepwater and ultra-deepwater reservoirs, with the aim of identifying leading concepts for future research, investment, development, testing and deployment /application.

The project will utilize current IOR/EOR evaluation work by Anadarko and its partners on the K2 Field to jumpstart closing the technology gaps that have prevented application of an EOR process in deepwater GOM. Advanced experimental fluid and core studies are being conducted to improve understanding of reservoir process mechanisms for water-based and gas-based injection processes determined to be the most feasible injectants for deepwater reservoir conditions. A comprehensive description of the K2 EOR evaluation and initial fluid studies work is documented in OTC paper 19624 to be presented at the May 2008 Offshore Technology Conference in Houston, Texas.

State-of-the-art and unique measurement techniques currently in place at LSU will be upgraded to characterize DW/UDW reservoir fluid-fluid and rock-fluids interactions at actual reservoir conditions of pressures and temperatures. This will aid in making key decisions on the IOR processes suitable for DW/UDW applications. A thorough and comprehensive review of IOR/EOR techniques and experiences, both on- and offshore, will be conducted.

Project results will be captured in a knowledge base to facilitate effective technology transfer. The primary outcomes of the project will be advancement of understanding of improved recovery techniques, provision of a foundation for future development, testing and deployment phases of new technology and methodology, ultimately leading to the recovery of more resources from deepwater and ultra-deepwater assets.

Research Area: Met-ocean

Project Title: **1801 – Effect of Global Warming on Hurricane Activity in the North Atlantic**

Performer: National Center for Atmospheric Research

Project Abstract

Project Overview: The study will conduct an assessment of potential impacts of global warming on North Atlantic hurricane activity with a focus on the Gulf of Mexico. The large-scale component will be provided by existing global climate simulations from the NCAR CCSM3 archive of simulations undertaken for the IPCC. This is one of the best global climate models and by using the IPCC archive we are assured of a simulation set that has been thoroughly and critically examined by the scientific community and has well understood characteristics. These global simulations are of too course a resolution for assessing hurricane activity, so we plan to nest the NCAR Advanced Research Weather
Research and Forecasting (ARW) model in its Nested Regional Climate Model (NRCM) mode into the
CCSM3 and conduct a set of high resolution downscaling simulations for current and future climate. This work will be conducted in collaboration with an ongoing NCAR downscaling program for high-impact weather, thus substantially increasing the available resources and enabling efficiencies through combination of the efforts. The hurricane results will be used to advise RPSEA on how much the hurricane intensity and frequency is likely to change in the Gulf of Mexico over approximately the next 50 years. All data will also be archived and made available for further studies on hurricane responses to climate variability and change.

Project Impacts: Since the disastrous 2004 and 2005 hurricane seasons, there has been a considerable amount of debate on whether we are currently seeing impacts of global warming and on what the likely future changes will be. The debate has at times been acrimonious and the lack of hard evidence has left open opportunities for misinterpretation and justification of pre-existing beliefs. In addition to the immediate findings that will be relayed as a direct result of this study, NCAR will, with RPSEA's approval, archive all simulations in a form that will be readily accessible to other researchers, thus enabling a wider group to investigate this important issue. We also envisage using the these initial simulations as a basis for future simulations at higher resolution and with improved physics as computing systems and our overall knowledge improves.

Research Area: Systems Engineering and Architecture

Project Title**: 1302 - Ultra-High Conductivity Umbilicals: A Paradigm Change in Conductors Using Carbon Nanotubes**

Performer: *Technip, USA*

Project Abstract

Numerous developments have occurred that will enable the next generation of Ultra-High Conductivity Umbilicals for deep sea oil and gas production. These developments have occurred in the new field of nanotechnology and have been sparked by the exciting properties of Single Walled Carbon Nanotubes (SWCNTs). To this end, nanotubes in copper and other metals have shown promise for improved properties including electrical systems. Even lighter weight polymers with dispersed nanotubes have shown high electrical conduction with enhanced strength. Furthermore, the Armchair Quantum Wire (AQW) is a conductor cable with great promise that should be a paradigm change in the way power is distributed. The precursor to the AQW that is proposed is the Polymer Nanotube Umbilical (PNU) (conductivity that will be about four times that of copper) because it is an ultra high conductivity wire and can be delivered in the next three years. These last two systems (the AQW and PNU) provide new opportunities for electrical conducting cables that could be used for the new frontiers of oil and gas production. When considering high power requirements and long umbilical tie-back distances, there is a need for new technologies to enable power delivery to the seafloor. Carbon nanotechnology is one such new technology that could enable high power transfer for long tieback distances where lightweight and high power transfer are required. In this proposal, the opportunities from carbon nanotechnology will be described along with the development plan for a new high current density electrical wire (PNU) based on SWCNTs dispersed in a polymer binder. The new wire has the ability to be processed at long lengths with connections that could be made at numerous points along the length. This low current loss wire can be bundled into an umbilical to provide power for communication lines and to operate pumps and other subsea equipment.

Project Title: **1401- Composite Riser for Ultra-Deepwater High Pressure Wells**

Performers: *Lincoln Composites*

Project Abstract

This proposal to develop a Composite Riser for Ultra-Deepwater High-Pressure Wells Program together with the U.S. Department of Energy and the Research Partnership to Secure Energy for America and Lincoln Composites, Inc. a member of the Hexagon Composites Group, will develop and build a cost-effective composite riser solution suitable for use in ultra-deepwater high-pressure wells where supporting the weight of an all-steel riser solution becomes problematic. Led by Project Director Donald Baldwin, whose experience in this field spans more than 22 years, Lincoln Composites will incorporate Lincoln Composites' patented structural composite/steel trap lock interface in a hybrid composite riser capable of more than a 50% weight reduction compared to all steel risers. The weight reduction possibilities of a hybrid composite/steel riser system would enable access ultra-deepwater high-pressure reservoirs that would otherwise prove cost ineffective or technically not possible by conventional all-steel means.

The objectives of Phase 1 of this project include complete Basis of Design study and analysis to determine appropriate criteria for design and analysis as well as fabrication and proof of concept testing of full-diameter, length-scaled riser joints. The primary objective during this stage of the program is to create a riser system that satisfies regulatory concerns, industry performance standards and sufficient margins of safety to eliminate apprehension at the operator level. It is the intent of this proposal to provide a deepwater solution and enable access to oil reserves previously unreachable, yet with current top-side tension capabilities. The result of Phase 1 of RPSEA DW1401 will be a solution that is ready for trial/use in the field with proven top-side TLP and SPAR technology under similar load conditions at water depths far exceeding current capabilities. Upon the conclusion of Phase 1 of this RPSEA proposal, Lincoln Composites would complete the design for a full scale trial specimen to be fabricated and deployed for use in field trial efforts.

Lincoln Composites will utilize previous experience in the hybrid riser field, state of the art finite element modeling software for hybrid composite structures as well as collaboration with industry experts in large scale design and testing methods. Stress Engineering Services will provide testing and consulting services as part of this proposal. Their contribution adds a tremendous amount of experience and understanding of field use requirements un-rivaled in the industry.

Project Title: **1402-A: Ultra-Deepwater Dry Tree System for Drilling and Production in the GoM, Phase 1**

Performer: *FloaTEC, LLC*

Project Abstract

The RPSEA study for Phase 1 of an "Ultra-Deepwater Dry Tree System for Drilling and Production in the Gulf of Mexico" provides the opportunity to develop and evaluate competitive platform concepts that can facilitate the development of oil reserves in the U.S. Gulf waters.

FloaTEC, LLC, a 50:50 joint venture company created by J. Ray McDermott (JRM) and Keppel FELS (KFELS) to deliver deepwater floating production systems, will lead the study effort. FloaTEC intends to supplement their team by utilizing their parents' expertise in the areas of constructability in design, fabrication and installation, and by engaging specialist companies: 2H Offshore, VetcoGray, and Seadrill Americas, Inc. in the areas of riser analysis, riser and tensioner hardware, and drilling rig layout and operations, respectively.

The Project Director for FloaTEC is Mr. Jing Kuang. He will be assisted by Bala Padmanabhan, C. K. Yang, H. S. Lee and Shirish Potnis (all FloaTEC), Pranab Sarkar and Darryl Payne (J Ray McDermott), Chau Nguyen (2H), C. R. Lin (VetcoGray) as his principal investigators/lead engineers in the project team.

The main objectives of the project are to assess alternative dry tree semisubmersible concept designs for two different payload cases in accordance with the agreed basis of design, and select one hull form option for model testing and further development in Phase 2 of the RPSEA program. The intent is to investigate the feasibility of developing these platform designs and to identify any technical limits to areas where further qualification or testing will be required in the industry.

The project is divided into distinct areas of scope. The initial task is to jointly develop the basis of design for the project, followed by a sizing exercise to be able to compare all dry tree platform and riser options selected for study. A comparative assessment of the results of this task will be presented and evaluated at a workshop. The outcome of the workshop will be the selection of two dry tree hulls and riser forms (one combination for each of the two payloads considered) for further evaluation and refinement.

FloaTEC's in-house sizing tools enable the hull options to be developed on an equal basis, providing the necessary data to estimate costs to the screening level accuracy required for comparison. Similarly, the experience of the other members of project team will provide the necessary input to accurate payload development, riser and tensioner component sizing, project execution plans, and cost estimates.

The two options selected for further study will be developed to the extent necessary to ensure their feasibility in all areas, and provide sufficient detail to develop +/-30% cost estimates. A second workshop will be held to select one case to be model tested. Model testing will be performed at a reputable, experienced facility.

All results of these tasks will be assembled into a final report, and agreement will be reached on an appropriate method to transfer technology to industry.
The major outcome from the project will be an assessment of the competitiveness of a dry tree semisubmersible to the limited production platform concepts currently available for field developments in deep waters (over 6,000 ft). Any technology requiring development will be identified, allowing an accurate timeline to be established for product readiness.

Project Title: **1402-B: Ultra-Deepwater Dry Tree System for Drilling and Production in the GoM, Phase 1**

Performer: *Houston Offshore Engineering*

Project Abstract

This document describes Houston Offshore Engineering's proposal for the research and development project, "Ultra Deepwater Dry Tree System for Drilling and Production in the Gulf of Mexico." The principal technical staff proposed for the project includes Jun Zou (PhD, Manager of Naval Architecture), responsible for global configuration, global performance analysis and model test execution, and Shan Shi (PhD, Manager of Riser Systems), responsible for riser configuration, riser analysis and riser systems integration. Philip Poll (Manager of Projects) will provide overall project direction and coordination.

The primary objective of the proposed work scope is to develop a floating system concept that is suitable for drilling and production in ultra deepwater using dry trees. A second, equally important objective is to perform engineering, testing and other activities to mature the concept so that the technology is ready for implementation by oil and gas operators in the Gulf of Mexico. This commercialization objective is very important because without this step, the research and development does not provide any strategic benefit to the oil and gas industry or the United States government.

The project execution plan for this development program incorporates critical subcontracts to bring world-class expertise in the areas of hull constructability (Keppel Fels), topsides fabrication and integration (Kiewit Offshore) and model test facilities (Offshore Technology and Research Center). The combined team incorporates all the expertise necessary to ensure that the results of the research and development is a concept that will meet all functional requirements and can be built, integrated and installed using conventional facilities.

The potential impact of the project is tremendous. The benefits of dry tree development of oil and gas include increased total reserve recovery and lower cost access for well workover and maintenance. Without dry tree access, oil and gas production becomes subject to availability and cost of mobile offshore drilling units, which in the current market are difficult and expensive to contract. The existing dry tree concept for deepwater includes significant challenges and risks, including offshore integration, limited and congested wellbay area, and limited facilities for hull fabrication and transportation. A new dry tree system for ultra deepwater Gulf of Mexico has the potential to increase total reserve recovery for the United States and lower the overall cost for extracting hydrocarbons from beneath the sea floor.

Project Title: **1501 - Grand Challenge – Extreme Reach Development**
Performer: *Tejas Research and Engineering*

Project Abstract
The "Grand Challenge" is to conceptualize a new integrated drilling and completion technology which is capable up to a 20 mile offset reservoir development. This would provide significant development alternatives that are not technically possible today. When the feasibility of this technology is demonstrated, it will deliver development flexibility and favorable economics either in either deepwater or anywhere surface vertical access to reservoirs may be limited or obstructed. (e.g. under seasonal shorefast ice, or environmentally sensitive areas).

Extreme Reach solutions that will be found in the RFP2007DW1501 deliverables which will provide the rudimentary steps to enable some "impossible" field developments, more completely drain existing reservoirs, or to reduce the cost of existing recovery methods. Further, the subject technology has the potential to significantly reduce the environmental "footprint" of hydrocarbon drilling and production whereby a single location may be able to drill and produce hydrocarbons beneath nearly a million surface acres.

By any yardstick, this project is outside "conventional" boundaries, and employs altogether new concepts vis-à-vis well construction and architecture. However, many elements of this technology are very conventional and well known to those in the oil industry. This project will create "virtual" models and animations of the unique combinations of these familiar elements. Specifically, each commercially available component will be constructed in PTC's "Pro-Engineer" software – completely to scale. Other components will be modeled from "as built" parts, subassemblies, or engineered from scratch. A solid model of the assembly will be made of a preferred embodiment. The assembly will be animated, illustrating how the moving parts interact as the tool operates through a cycle.

Upon completion, this small project will effectively communicate these concepts, and facilitate a more complete understanding to industry professionals. Convincing people that the Grand Challenge – Extreme Reach can be done (and must be done) is an essential first step to getting it done.

This project will conceptualize a new integrated drilling technology which is capable up to a 20 mile offset reservoir development. This is accomplished by a unique "Tractor" that attains locomotion similar to a pipeline "pig", by application of differential pressure across a set of resilient cups or discs. The Tractor also includes many familiar components: an electric motor, a pump, a gearbox, centralizers, a power umbilical, and various interface connections to enable tasks to be accomplished downhole. Implements may be attached to the tractor to accomplish these tasks, wherein the assembly of the tractor and implements creates a unique Bottom Hole Assembly capable of constructing a well, maintaining it over its service life, as well as P & A operations.

This project will illustrate the technical aspects of the Tractor, BHA, and topside equipment at a high level, so that the concepts can be easily understood by industry professionals.

Project Title: **1603-A: Graduate Student Design Project – Flow Phenomena in Jumpers – Relation to Hydrate Plugging Risk**
Performer: *The University of Tulsa*

Project Abstract

The project director and principal investigator to carryout the proposed work is Dr. Mike Volk who is the Associate VP of Research and Technology Development program at the University of Tulsa. The industry participant is Chevron. The project title is: **Flow phenomena in jumpers – Relation to hydrate plugging risk.**

In deepwater and ultra-deepwater systems, hydrate formation and plugging is the number one concern because of the difficulty to remediate hydrate plugs and the associated lost production costs. Design solutions such as flow line insulation and inhibitor injection - such as methanol - constitute the standard engineering methods deployed to avoid hydrate formation and plugging. Restart scenario and profiles are evaluated using state-of-the-art transient flow models. Despite very conservative standards and operating strategies, plug formation is still not completely avoided, and the production jumpers seem to be at a higher risk during restart operations, in part because of their geometry, the difficulty to insulate such geometries and a probable misunderstanding of the complex flow patterns and phenomena taking place in the jumper during restart. Once a plug is formed in a jumper, current jumper designs make it difficult to remediate the plugs, leading to very large remediation costs.

This project proposes to utilize the know-how and infrastructure available at the University of Tulsa Hydrate research project to improve the understanding of liquid displacement and flow pattern in jumper-like systems during restart operations. Previous research at TU has shown the importance of the presence of a free-water phase and its displacement on the plugging tendency of a system.

The project will study the displacement of the oil and water phases during restart in a jumper configuration and comparisons will be made with existing transient simulators to validate transient flow models. Effects of liquid loadings, water loadings and restart rates will be studied on the displacement of the water phase. From this work, improved restart strategies to avoid plugging with a free water phase in a jumper may be developed, and confidence in existing prediction models improved. Additionally, data collected from this project may lead to better prevention methods, such as better methods to displace water out of a non-inhibited jumper while avoiding plug formation. Inhibitor distribution and displacement can also be studied in this facility, which may lead to better design of injection points in jumpers.

Project Title: **1603-B: Graduate Student Design Project – Hydrate Characterization & Dissociation Strategies**

Performer: *The University of Tulsa*

Project Abstract

The project director and principal investigator to carryout the proposed work is Dr. Michael Volk who is the Associate VP of Research and Technology Development program at the University. The industry mentor is George Shoup from BP. The project title is: Plug Characterization and Dissociation Strategies.

While there are a number of cases for formation and recovery of hydrate plugs, very few have been quantified for model baselines to enable future plug prevention. When plugs form, invariably it is an emergency situation, so that plug data are not gathered in an accurate and deliberate manner suitable for documentation. As experience-based hydrate kinetic models are developed it will be important to combine them with transient flow simulation tools to predict plug location and timing. Efforts are ongoing to incorporate hydrate kinetic models into industrial transient simulators. It is vital to benchmark such predictions, against thoroughly-documented flow loop and field studies of hydrate plugs.

In deepwater oil wells, thermodynamic conditions are favorable for the formation of hydrates which tend to agglomerate and eventually plug pipelines. One of the offshore industry's major concerns is how to eliminate hydrate plugs from pipelines after they form due to the difficulty and costly nature of the hydrate remediation techniques. Different remediation strategies, such as melting, depressurization and inhibitors, may be implemented but little is known about the properties of the plug, mainly, the effective porosity and permeability to gas or liquids, and therefore, little is known about the most efficient dissociation methods under certain conditions. The main objective of this proposal is to bridge the knowledge gap between plug characterization and dissociation, leading to the selection of the most effective plug dissociation method for different plug scenarios.

The University of Tulsa will utilize its Flow Assurance Loop (FAL) to conduct the work proposed in this study with some minor modifications. The facility consists of a 3" pipe flow loop mounted on an 80-ft long tilt table. The flow path is 160-ft long and fluids can be set in motion by a Leistritz twin-screw multiphase pump or by the rocking motion of the flow loop deck. The process building contains all the equipment necessary to charge oil, water, and gas into the flow loop. The control trailer contains all the data acquisition modules and the operator computer interface.

Solid hydrate plugs will be formed in the high pressure flow loop by installing a witch's hat. The length and density of the plug will be obtained by using a scanning gamma densitometer to obtain porosity values for the plug. A new fluid handling system, composed of a heat exchanger, a three phase separator, and a volumetric tank, will be utilized for displacing the liquids out of the system by injecting gas. Pressure drop data will be acquired after all the mobile liquids are displaced leaving only trapped liquid in the plug. Permeability values will be calculated from the pressure drop data and plug length measurements. Finally, different dissociation strategies will be applied to the plug, mainly, depressurization, wall heating and inhibitor injections (MEG and Methanol). A comparison of the dissociation times will be provided.

Knowledge of typical plug characterization, permeability and porosity, will be the key to evaluate the feasibility of some dissociation techniques. This research will introduce a new technology to characterize hydrate plugs and criteria for selecting the most effective dissociation technique. A graduate engineer will enter the industry with knowledge of how hydrate plugs form, what are plug properties and state of the art knowledge of the best approach to remediate the plug.

Project Title: **1603-C: Graduate Student Design Project – Design Investigation of Extreme High Pressure, High Temperature, (XHPHT), Subsurface Safety Valves (SSSV)**

Performer: *Rice University*

Project Abstract

The Research Partnership to Secure Energy for America (RPSEA), Technical Focus Area 4 – Step-Change Technology seeks novel technologies which ***may*** result in improved ultra-deepwater production systems. Sub-Surface Safety Valves (SSSV) are a technology that ***must have a step change*** in capabilities for extreme high pressure, high temperature (XHPHT) discoveries to become safely producible. Even in the current (15 ksi pressure) environments the major producers have concerns about structural safety, and fluid structure interactions. At the new 30 ksi pressures, and higher temperatures, an incremental change in current designs will likely not be sufficient. New approaches to SSSV design, through a graduate level task design can only help in developing the XHPHT resources.

Project Title: **1603-D: Graduate Student Design Project – Robotic MFL Sensor for Monitoring and Inspection of Deepwater Risers**

Performer: *Rice University*

Project Abstract:

The objective of this proposal is to develop inspection robots and nondestructive evaluation sensors for on-site inspection of risers in deepwater offshore platforms. We propose a two pronged strategy (1) development of a detailed analytical model of a deepwater semi-submersible platform and risers, with coupled analysis floating platform/mooring/risers, and to establish the dynamic response of riser for fatigue crack evaluations, and (2) experimentally evaluate remotely operated nondestructive evaluation sensor on a small scale riser at Rice University in collaboration with itRobotics, under dynamic response [computed in task 1] to which the riser is subjected to under normal and adverse operating conditions. The new idea that is being proposed in this study is to develop promising nondestructive (NDT) technique such as Magnetic Flux Leakage (MFL) mounted on tether less mobile remotely operated robot to detect defects and fatigue cracks in real time. Such concepts have not been evaluated for large diameter deepwater risers. The performance objectives are an NDT MFL sensor carried by a remotely operated robotic crawler inside the riser, the displacement of which is monitored and controlled as it traverses the riser, and which provides indication of the structural integrity of the metallic components of the riser in real time. We will also develop new damage detection algorithms based on system identification and control theory. We will correlate the results of MFL technique with results of existing techniques. Technology transfer of the developed techniques will be given priority. The funding requested is for two years, is for a graduate student, who will be supervised by Professors Satish Nagarajaiah and Fathi Ghorbel of mechanical engineering and material science department at Rice in collaboration with itRobotics.

Project Title: **1701 – Improved Recovery**
Performer: Knowledge Reservoir, LLC

Project Abstract
This project is titled Development of a Research Report and Characterization Database of Deepwater and Ultra-Deepwater Assets in the Gulf of Mexico, including Technical Focus Direction, Incentives, Needs Assessment Analysis and Concepts Identification for Improved Recovery Techniques. The project will be led and directed by Knowledge Reservoir LLC, with primary project participants Louisiana State University, Anadarko Petroleum Corporation. Additional participants are Schlumberger, Core Laboratories and CMG.

Steven Knabe, Vice President, Production, Drilling & Completions for KR will be Project Director and the Principal Investigators will be Dandina N. Rao, Ph.D., P.Eng. Emmett C. Wells Jr. Distinguished Professor; Associate Professor, Craft & Hawkins Department of Petroleum Engineering, LSU and Frank H Lim, Senior Reservoir Engineering IOR Advisor, APC.

The project will identify improved recovery opportunities in the early stages of field development planning, such that facility and well designs can be optimized to take advantage of those opportunities. Additionally, opportunities for improved recovery in producing fields will be assessed, as will current and near-future technologies for improved recovery. The project will include characterization of deepwater and ultra-deepwater reservoir assets and compile and categorize key causes of trapped and remaining hydrocarbons in such reservoirs. The prioritization of technology gaps in improved recovery methods will also be addressed as specifically relate to deepwater and ultra-deepwater reservoirs, with the aim of identifying leading concepts for future research, investment, development, testing and deployment /application.

The project will utilize current IOR/EOR evaluation work by Anadarko and its partners on the K2 Field to jumpstart closing the technology gaps that have prevented application of an EOR process in deepwater GOM. Advanced experimental fluid and core studies are being conducted to improve understanding of reservoir process mechanisms for water-based and gas-based injection processes determined to be the most feasible injectants for deepwater reservoir conditions. A comprehensive description of the K2 EOR evaluation and initial fluid studies work is documented in OTC paper 19624 to be presented at the May 2008 Offshore Technology Conference in Houston, Texas.

State-of-the-art and unique measurement techniques currently in place at LSU will be upgraded to characterize DW/UDW reservoir fluid-fluid and rock-fluids interactions at actual reservoir conditions of pressures and temperatures. This will aid in making key decisions on the IOR processes suitable for DW/UDW applications. A thorough and comprehensive review of IOR/EOR techniques and experiences, both on- and offshore, will be conducted.

Project results will be captured in a knowledge base to facilitate effective technology transfer. The primary outcomes of the project will be advancement of understanding of improved recovery techniques, provision of a foundation for future development, testing and deployment phases of new technology and methodology, ultimately leading to the recovery of more resources from deepwater and ultra-deepwater assets.

Project Title: **1901 – Subsea Processing System Integration Engineering**
Performer: *General Electric*

Project Abstract
GE will develop and validate a physics-based subsea separation simulator that will be suitable for use by both the equipment suppliers and the facility engineers to predict system performance with confidence. The outcome will be a software tool capable of simulating multiphase flow subsea processing systems that will be ready for further expansion and validation in the subsequent pilot and full-scale testing phases of the project.

GE Global Research and VetcoGray, a GE Oil and Gas business, will execute the project. Mark Lusted (GE Global Research) will be the project director, Dan Friedemann (GE VetcoGray) will be the technology lead and David Anderson (GE Global Research) will be the principal investigator. This team brings unique and comprehensive capabilities to this project including:

- World-class understanding of subsea technologies
- Proven experience in experimental testing of multi-phase flow phenomena
- In-depth experience with modeling, designing and fielding subsea systems
- Broad experience with the full range dynamic simulation tools for operational performance prediction

As existing well depletion and increasing oil and gas demand drive toward production from increasingly challenging assets, Subsea Processing (SSP) at increasing depths (up to 3000m) and pressures (>300 bar) is becoming ever more important. Separation of multi-phase flow is a critical element of such SSP primarily to increase production rates and total production via supporting pumping and compression, and remedy flow assurance challenges. Despite the assertions by equipment suppliers that Compact Subsea Processing Systems are ready for deployment, operating engineers remain less certain of that readiness due to a lack of a robust simulator able to predict system performance (in particular separator performance) throughout a full range of possible operating conditions.

The objective of this project is to develop and validate a physics-based simulator capable of predicting the separator performance over the range of conditions and fluid compositions found in the Gulf of Mexico. Combining GE VetcoGray's experience with SSP and GE Global Research's experience with testing and simulation, GE will develop a hierarchical simulation model with four tiers: component model library, separator, separation system and statistical performance solver wrapper. This simulator will be validated at the component and simulator levels in an existing GE multiphase flow test loop optimized for this project and scaling rules will be developed to predict performance at full-scale size and pressures. The hierarchical structure of the resulting simulator will have the flexibility at the component- level to be expanded as better physical descriptions of components become available, and the Simulator will interface directly with existing production modeling software such as OLGA.

Ultimately, by bringing to bear the combined expertise of Global Research and

VetcoGray in the rapid fielding of technology, GE will develop a technology transfer plan with RPSEA to ensure software enhancement through beta user input and rapid, widespread acceptance of the Simulator throughout the industry.

Project Title: **1902 - Deep Sea Hybrid Power Systems - Phase 1**
Performer: *Houston Advanced Research Center*

Project Abstract
The Houston Advanced Research Center (HARC) will partner with Lawrence Livermore National Laboratory (LLNL), Naval Facilities Engineering Service Center, Yardney Technical Products, Shell, Chevron and GE to evaluate alternative methods for locally generating significant electrical power on the seafloor near large consumption points. Dr. Richard C. Haut from HARC will be the Principal Investigator leading the team effort with the objective of developing hybrid energy conversion and storage systems for deep ocean operations. Such power systems will be located on the oceans floor, and will be used to supply oil and gas exploration activities, as well as drilling operations required to harvest petroleum reserves.

An investment in subsea (deep-ocean) hybrid power systems is required to enable offshore oil and gas exploration and production. Advanced deep-ocean drilling operations, locally powered, will provide access to oil and gas reserves otherwise inaccessible and could decrease the air emissions associated with offshore operations. Such technology will therefore enhance the energy security of the United States. There is a strong driving force for the development of subsea capabilities on the ocean floor. Such facilities will require ample supplies of local power to operate machinery on the floor, ranging from drills to pumps and compressors.

Several potential systems for energy generation and storage technologies for unattended environmentally friendly deep-sea application, will be systematically screened during the Phase I effort of the project. Following the screening phase, work will then transition into the design and fabrication of prototypes, with both surface and sub-sea testing, Phase II. The successful technology will then be commercialized through appropriate industrial partnerships.

The proposed work will begin with the definition of systems requirements, and the establishment of quantitative and qualitative selection criteria. These criteria will be used to guide the development of subsea hybrid power system suitable for powering oil and gas equipment on the ocean floor. The existing knowledge base of high-performance energy conversion and storage systems, appropriate for underwater applications, will be used as the basis of several conceptual designs, and then those conceptual designs will be systematically screened for the best hybrid system. The data base will be archived in technical reports for use by the oil and gas industry. The selection will be performance-based, and done in a way to screen out any potential biases towards a particular technology. Following selection of the most promising generation-storage combination, a detailed conceptual design will be developed, for both a subscale prototype for initial testing and demonstration, and for a full-scale system to serve as the basis for precise economic evaluation. The prototype will then be constructed, leveraging several of the team's relationships with other organizations, and tested at operating pressure in collaboration with the Navy. With adequate high-pressure cold performance of the prototype demonstrated, the system will then be deployed to the ocean floor for additional performance testing. After satisfactory ocean-floor testing, the Procurement Programs of the various Team members will be exploited for RPSEA, to integrate those vendors required for initial deployment, with involvement of partners from the oil and gas industry.