TASK 11
BUSINESS CASE &
COMMERCIALIZATION PLAN
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Coiled Tubing, Drilling & Intervention System
Using Cost-Effective Vessel

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Charles R. Yemington, PE
Project Manager
Nautilus International LLC.
400 N. Sam Houston Pkwy. East, Suite 105
Houston, TX 77060
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TASK 11 FINAL REPORT

BUSINESS CASE & COMMERCIALIZATION PLAN

RPSEA PROJECT 1502-01

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1.0 EXECUTIVE SUMMARY

RPSEA Project 1502, Phase One, was undertaken to investigate the feasibility of installing a Self-Standing Riser (SSR) to an existing deepwater production tree to enable intervention to the well with a coiled tubing or wireline string where circulation could be established between the well and the intervention vessel, and where the coiled tubing or wireline could be used for normal in-well intervention work. This is referred to as the “SSR System” in this report. The project included investigation of the use of existing intervention vessels operating in the Gulf of Mexico (GOM). Technical documents were created as the foundation for future work to commercialize the technology and make it available as an aid to future deepwater production in a safe and environmentally responsible manner.

Nautilus compiled a thorough report of prior technology in Task 2 “The Technology Assessment for the Application of Coiled Tubing in Deepwater Subsea Wells”. The Task 2 report covers four major topics: Coiled tubing technology; Deepwater intervention; Vessels to deploy the coiled tubing equipment; and Subsea equipment to accommodate the use of coiled tubing to intervene into a subsea well. The Technology Assessment Report covers the state of the art pertaining to these sub-topics with supporting references for those who want to broaden their understanding.

The system architecture for the proposed approach was developed in Task 5 and documented in the System Architecture and Design Basis report. This report established the core objectives for the project with the overriding goal to develop a safe and cost-effective system. The document served as the design basis document for subsequent tasks, and findings of the work on those tasks were later incorporated so that the documents could also serve as the design basis document for future work.

Conceptual design work resulted in the System Conceptual Design and Analysis Architecture report. The conceptual design included consideration of a two-vessel approach that allows a small construction vessel to install and recover the riser out of the critical path for intervention by a vessel specialized for downhole work. This approach improves safety by reducing the number of personnel offshore at any one time and by separating riser installation, which is essentially a construction task, from downhole work which may involve handling of hydrocarbons. This
allows the riser installation vessel to be optimized for safe, efficient construction work while the CT intervention vessel is optimized for downhole intervention, including handling potentially hazardous or flammable fluids and returns.

Procedures were then developed for mobilization, offshore operations, maintenance and contingencies. Reliability analysis and cost estimates were included in the Operations Analysis report and serve as the basis for establishing commercial feasibility of the proposed approach. The task report covered routine and emergency disconnection, safety of operations procedures both for systems, downhole work, and components.

The conceptual design and the operational procedures were subjected to HAZID review as a step in establishing the commercial feasibility and practicality of the proposed approach. The Task 8 HAZID Study and Report documents the results of planning and review meetings which brought together 24 industry experts, including operator advisors, to address issues on the design and safety operations of using the SSR for deepwater well intervention with wireline and coiled tubing. The conceptual design and the results of the HAZID were reviewed with regulatory representatives to confirm that the proposed concept is suitably aligned with regulatory objectives and requirements in the post-Macondo environment. The task report provides strong support for a field demonstration project of downhole well intervention using a modular, reusable SSR and vessels that are more cost-effective than offshore drilling vessels.

Further design work was then done on system components that are significant for environmental protection or that might have a significant impact on system cost. Results were documented in a Component Design report that includes equipment where existing designs must be adapted to enable the SSR system to be utilized with cost-effective vessels. Of particular importance in this report is a focus on safety equipment, including the seafloor shutoff device which is intended to meet all reservoir containment requirements. Management of the relative motion between a small vessel and other system elements, for both riser installation and downhole operations, is also addressed and shown to meet both safety and material fatigue life objectives.

Vessel day rate is by far the highest cost element for most offshore work. This is also true for the proposed system, even though it uses vessels that cost far less than a drilling vessel. A substantial effort was therefore applied to defining the vessel requirements, including deck
space, dynamic positioning, and equipment for both riser installation and downhole operations. Consideration was given to both vessels of opportunity and custom outfitted vessels that would be used in an ongoing business. Available vessels were identified and their day rates, mobilization requirements, and support requirements were established and incorporated into the cost estimates for both demonstration and commercialization of the proposed approach.

This Task 11 report shows how the results of the work summarized above establish the commercial practicality of the proposed approach. The approach is particularly attractive in that it is both a cost-effective approach to meeting existing needs for deepwater well intervention and also makes significant advances in the areas of personnel safety and environmental protection.
2.0 MEETING COMMERCIAL AND PUBLIC NEEDS

There were fewer than ten subsea completions per year until 1993, but this number increased dramatically throughout the 1990s and today. Shallow-water subsea wells (< 2,000 ft water depth) began to make up a significant proportion of the total number of GOM subsea wells accounting for 151 of the 348 subsea wells by year-end 2005. Operators have found subsea tiebacks to be valuable for marginal shallow-water fields because of the extensive infrastructure of available platforms and pipelines. As a result of these factors, there has been an increasing reliance on subsea technology to develop shallow-water.

The technology required to implement subsea production systems in deepwater has evolved significantly in the last 17 years. A water depth of 350 ft was the deepest subsea completion until 1988, when the water depth record for the GOM jumped to 2,243 ft (Green Canyon 31 project). In 1996, another record was reached with a subsea completion in 2,956 ft of water (Mars project), followed by a 1997 subsea completion in 5,295 ft of water (Mensa project). The record in the GOM was then taken by Coulomb in a water depth of 7,591 ft and later overtaken by Independence Hub and others. A number of deep projects are being planned and developed (see MMS chart). Nearly 70% of subsea completions are in water depths of less than 2,500 ft. However, the number and percentage of deepwater subsea completions is rising. The reason subsea wells continue to advance to greater water depths and harsher environments are the technological improvements, particularly related to flow assurance. While the technology has improved, the cost is still high and the challenges of well completions and intervention compound these costs.

Until the riser challenge is solved, either by the proposed approach or some other as yet unknown approach, deepwater interventions for satellite wells will be conducted by mobile offshore drilling units (MODUs), large intervention vessels with risers, or in some cases by riserless intervention systems. The proposed approach offers a safe, cost-effective alternative.

The high cost for existing deep water intervention systems result in most deepwater satellite wells being shut in and abandoned if a downhole problem is encountered. This leaves substantial volumes of recoverable resources in the ground, even though the cost and risk associated with drilling and completion have already been taken. The proposed approach is expected to substantially increase the recovery of resources from existing satellite wells without
significant increase in cost or risk by putting wells back into production rather than prematurely abandoning them.

The self-standing riser and coil tubing approach for deepwater intervention is expected to create a substantial new deepwater sub-industry that does not exist today. Vessels can be made in the U.S. from existing older work boats and other similar vessels. These vessels, designed to install and remove the SSR and deploy the coiled tubing, would add a fleet of support vessels to the GOM and create new employment that does not exist today. Because of the simplicity of the technology for building and operating these vessels, the barrier to entry into the marketplace would be low, further encouraging competition and domestic industry investment.

The use of the SSR for deploying coiled tubing is another market that currently does not exist. Large numbers of reusable SSRs could be easily made in coastal area facilities and leased for temporary service. Sub industries to build components and instruments for the self-supporting risers would also add to the commerce of this intervention approach.

All of the equipment and services to deploy this SSR/CT technology favor a strong U.S. content for wherever the deepwater market exists.
3.0 RPSEA PROJECT 1502 RECOMMENDATIONS

The RPSEA 1502 project has shown that the SSR is enabling technology that will allow companies to cost-effectively produce more oil and gas in the GOM. Well intervention throughout the life cycle of a well (on land or offshore) is essential to maximize production. As long as the cost and logistics in deep water are barriers to well intervention, many wells will not be repaired in a timely manner or in a way that will maximize production. Many will be shut in prematurely. While this study focused on conducting well intervention with an innovative self-standing riser using coiled tubing, it also addressed the entire system and the question of how to conduct deepwater satellite well intervention as if it were in shallow water or even on land. While many workovers can be conducted with wireline or slickline, most workovers and re-completions require circulation, and the best and fastest way is to use existing coil tubing equipment and a small diameter riser. While coil tubing was deemed the best option, under current practices and technical limitations, it is rarely being used in deep water except off stationary platforms. This study has also shown that the SSR system is an attractive alternative to current riser technology. The project addressed the entire system so that a team of service providers or an integrator of the respective elements could conduct well intervention utilizing the SSR system.

The 1502 Phase 1 study looked at the five major components considered as the system:

1. Capability of coiled tubing to operate in the GOM deepwater environment (physical properties of the coiled tubing string for various pressures, depths, and internal diameters);
2. Design and operation of a SSR that would connect to an existing production tree;
3. The safety designs that would demonstrate that a SSR could operate in the GOM deepwater environment where the well is under constant control, that the coiled tubing could be cut in the event of a vessel drive off or some other event requiring a quick departure from the well;
4. The feasibility for using a non-MODU vessel to install and remove the SSR and to support the intervention activities, and
5. The cost effectiveness for using the SSR for intervention activities in the GOM.
The two-vessel approach is highlighted in the report; one vessel to install and remove the riser and another to conduct the well intervention system. The design employs a small vessel with limited deck space for each task. The two-vessel approach is not necessary, but, in addition to reducing the cost and risk, it improves scheduling flexibility by removing riser installation and recovery from the critical path. The SSR can be left unattended and, with its top 100 to 200 ft below the surface, is not affected by hurricanes, is not a hazard to navigation, does not require a marker buoy, and listing in the Coast Guard’s Notice to Mariners is not required. Only one vessel with only one set of equipment and personnel is needed in the field at any time because, with the exception of the Seafloor Shutoff Device, all active components can be recovered to the deck of the intervention vessel for maintenance.

Rig cost, mobilization costs, and operating costs have been estimated and compared to MODU cost estimates in support of Phase 2 planning. The results can be found in the RPSEA 08121-1502-01 Task 7 report.

MODU rates were compiled from public sources including RigZone and RigData Offshore, which are the basis for the averaged rig rates. These rates are based averages in the GOM at the end of the year 2010. Vessel Costs were also compiled from public sources and from ODS PetroData. It is noted that rates fluctuate based on worldwide supply and demand. Demand and day rates dropped significantly as a result of the Macondo spill and the following Department of Interior Moratorium and subsequent rule changes. The rates will continue to fluctuate and no doubt will rise when policy changes are completed and demand rises.
4.0 THE TARGET MARKET

Potential demand for the SSR system is one of the primary justifications for planning a demonstration phase. According to the Department of Interior Records through the end of 2009, there were over 3,000 subsea wells drilled including 1,006 Satellite deepwater wells in the GOM, 157 of which were shut-in and 30 which were abandoned. Records also show the majority of the wells had vertical trees. The need for intervention is growing exponentially. Whether it is a downhole tool failure, a build-up of sand, plugged perforations, need for stimulation, adding or repairing artificial lift pumps; or the need to plug back and side track to a new zone, some type of intervention is needed. The conventional method is to move in a MODU, run a standard subsea BOP and riser package, and do the necessary intervention using a combination of drill pipe, tubing, wire or electric line. The justification for adding coiled tubing to the operation does not make economic sense when MODU deck space is severely limited and the rig already has drill pipe available. This conventional approach, although being the most industry-acceptable, is also the most expensive. It requires mobilizing a MODU to do the operation, and the limited fleet of MODUs are also needed for exploration, appraisal, development drilling, and completions.

The market is growing. Nearly thirty billion barrels of oil have been discovered in the GOM and another forty-five billion barrels are estimated to be found (API Report-12-5-08). Nearly 220 Trillion Cubic Feet (TCF) of gas reserves have been discovered with an estimated 400 TCF yet to be discovered. An increasing number of the discoveries are small, cannot be made commercial with production facilities, and must utilize subsea completions with the production with tie-back to a host production facility. These tie-back completions will require regular well intervention, and it must be safe and economical.

Nautilus International recognized the need and compiled a strong and highly competent team to conduct the RPSEA 08121-1502-01 project. All coiled tubing service providers in the Gulf of Mexico and workover vessel companies were contacted. Nautilus International has made numerous presentations on the system. Ultimately there may be other players, providers or services when this system is deployed, and there may be other options to enhance the system given the particular needs of the operator and field requirements.
The overall market size is shown by the number of candidate wells. There are two distinct types of subsea wells that are the best candidates to utilize the SSR system for workover and maintenance. One is mature wells, some of which have already had workovers or recompletions and are in the latter stages of their economic life but could still produce additional oil and gas. This type also includes a growing number of fields that are candidates for water flood and improved oil recovery (IOR) as shown in the Knowledge Reservoir RPSEA report 07121-1701, titled IOR in the Deepwater Gulf of Mexico.

The second group of candidate wells is those recently drilled or still in the planning stage, particularly the more recent deepwater lower tertiary discoveries. Here the formation is thick and produces oil with a low gas-to-oil ratio, and the deep, cold water also impedes the viscosity of the oil, or the formation has low permeability and thus requires artificial lift to produce economically. These discoveries are being developed with a production facility and will include drilling satellite subsea completed wells because many of these discoveries have a huge aerial extent and the cost of satellite topside production facilities is cost-prohibitive. The added cost associated with the risk of hurricanes is also considered. The electrical submersible pumps that will be required to produce these wells are not reliable over an extended period of time and therefore require provisions for replacement. When the SSR coiled tubing approach is available, the operators will no longer be required to pay drilling contractors the premium rates for a MODU, so the economics and justification for drilling and producing these types of wells and adding artificial lift will improve substantially. To avoid unnecessary risk, the operator will need proof of the effectiveness and reliability of the SSR system and have access to a more cost-effective and reliable well intervention vessel and a service provider. A demonstration to prove this service to the operator could lead to the proposed approach being incorporated into long-term field development planning.

Recompletion of mature wells, coupled with the installation of electric submersible pumps (ESPps), has proven to be successful. BP, for example, in 2008 reported that installing ESPps in the 1981-discovered Pompano field in 1,300 ft water depth saw production increase three times the original rate, and production was limited only by the platform handling capabilities. If, as in this case, ESPps are installed from production platforms, the maintenance is not as problematic. However, the challenge of maintenance could prevent using this option on satellite subsea wells. A report on the logistics and cost for installing and maintaining ESPps in a candidate SS completed field using an SSR system has been proposed.
For 2010, the estimated average production in the GOM was 270 thousand barrels per day from shallow water and 1,500,000 barrels per day in deepwater. Two 2009 reports by the Department of Interior MMS (now BOEMR) project that total GOM production may exceed 2.1 million barrels per day if discoveries that have been announced by industry realize their potential.
5.0 DEMONSTRATION PHASE

Nautilus International LLC. has completed RPSEA project 08121-1502 for a coiled tubing system for downhole work in deepwater satellite wells using cost-effective vessels and a Self-Supporting Riser (SSR). The first phase of the project has clearly justified further work to commercialize this technology. Near-term work is required to add detail necessary in preparation for an offshore demonstration of the technology.

The primary objective of the next phase is to advance the recently completed RPSEA project work in preparation for a subsequent offshore demonstration of a cost-effective deepwater Coil Tubing (CT) system for downhole work in deepwater Gulf of Mexico satellite wells without need for a Mobile Offshore Drilling Unit (MODU). This work will facilitate improved resource recovery from existing satellite wells and make it practical to develop reservoirs that would otherwise not meet economic hurdles.

The recently completed work defined an effective, reliable deepwater coiled tubing system consisting of a vessel, conventional coiled tubing equipment, and a modular, reusable Self-Supporting Riser (SSR) that bridges the gap between the deck and the seafloor. The system accommodates heave, pitch, and roll of a small vessel and allows a large watch circle. The system is suitable for currents and conditions in the central Gulf of Mexico. Overall cost to deploy and operate the system is less than half the projected cost of a MODU. Tubing fatigue life is better than with conventional onshore CT systems. Fabrication and installation of a suitable modular SSR have been demonstrated. This previous work is to be used as the starting point for the proposed work.

The next step also includes specification of equipment and services, provisions to deal with hazards and failure modes identified by the earlier HAZID, and identification of a candidate well and sponsoring operator. Nautilus International met with the BOEMR in April 2011 to review the project findings and the HAZID report. The regulators made constructive recommendations to improve safety and well control from their understanding of how new regulations would be enforced. The most important result of the meeting was that they found the system to be well engineered, safe and potentially a superior alternative to current well intervention practices, particularly in regards to riserless intervention systems.
Nautilus is now fully committed to early commercialization to extend the life of existing wells and develop resources in a safe and environmentally protective manner that would otherwise not be commercially viable.

The next step for commercialization will demonstrate the viability of such a system where the risk and economics are attractive for an operator and service companies to support and participate in such a field demonstration.

This field test requires access to a deepwater well where a SSR could be attached to a wellhead or production tree in water depths that demonstrate the deepwater aspect of the field test. Because of the first-time aspect of the field test, it is desirable to lower the risk associated with hydrocarbons. The candidate well should therefore preferably have little or no pressure at the mud line.

A demonstration project will be conducted, subject to completing front end engineering and safety requirement work, approval by RPSEA and availability of RPSEA and industry funding, and commitment of a well by an operating company. The demonstration will include staging of equipment, mobilization to a vessel, and safe demonstration of downhole work using concepts developed as part of the 2010 and 2011 work. This work will require a permit, based in part on meeting regulatory requirements. Once approved, additional site-specific engineering, the System final design, and a HAZOP safety meeting will be required prior to construction and deployment.

The timing to build the SSR System, including the buoyancy device, would take a minimum of 6 to 9 months. Other long lead items such as the shear and seal rams may extend the schedule somewhat.

The cost of a field demonstration will include installation and removal, mobilization costs, the day rate for a vessel of opportunity, and the day rate for coiled tubing and/or wireline equipment. In the event an operator sees an application for demonstrating the use of the SSR approach while doing a meaningful well operation like plugging a subsea deepwater well, we anticipate the operator would be prepared to cover a significant amount of the SSR construction and mobilization costs.
The demonstration will ideally include downhole operations like setting packers, setting cement plugs, or plug and abandonment work. The budget will dictate the total number of in-riser tests. A controlled drive-off test could be done to demonstrate the functionality of the shear rams to sever the coiled tubing, contain the well, and hold the tubing.

Near-term activities to demonstrate the viability of the SSR system are contingent upon funding. If additional funding could be obtained, a series of other tests that would be meaningful for deepwater intervention using an SSR could be demonstrated. Examples of these are:

1. The deployment of an ESP on coiled tubing to the base of the SSR to demonstrate the use of an ESP on coiled tubing to enhance production rates;
2. The circulation of heated water to melt and remove hydrate plugs in production trees;
3. Various equipment like coiled tubing injectors, lubricators, shear rams, BOPs and other equipment could be tested; and
4. Use of the SSR for a Dual Gradient drilling project, where the SSR would be used as the return line to the MODU.
6.0 ESTIMATED COSTS

Rig cost, mobilization costs, and operating costs have been estimated and compared to MODU cost estimates in support of Phase 2 planning. The results can be found in the RPSEA 08121-1502-01 Task 7 report.

The estimates are based on using separate, specialized vessels for SSR installation and for downhole intervention. If a single vessel is used for SSR installation and operations, its higher day rate is partially offset by savings in mobilization and transit costs. For a single well intervention, if scheduling permits, the cost can be reduced by having the installation vessel standby for up to a week during downhole work. Similarly, if a vessel suitable for both SSR installation and intervention is available at a day rate of about $300,000, the cost can be reduced if this vessel can run, test, and recover the riser in less than 3 days.