Research Partnership to Secure Energy for America

DOCUMENT TITLE:
Self Supporting Riser Technology to Enable Coiled Tubing Intervention for Deepwater Wells

Document No.: 08121-1502-12

RPSEA PROJECT TITLE:
Coil Tubing Drilling and Intervention System Using a Cost Effective Vessel

RPSEA Project No.: 08121-1502

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Abstract

This report summarizes the task reports and other information gathered from the RPSEA Project, *Coiled Tubing Drilling and Intervention System Using a Cost Effective Vessel*. This project looked at the design, design verification, and feasibility of installing a modular, reusable Self Supporting Riser (SSR) on an existing deepwater satellite production tree or wellhead to enable intervention using Coiled Tubing (CT). The SSR effectively brings the seafloor closer to the surface which allows existing shallow water intervention methods to be used in deep water. The project shows how to safely use cost-effective vessels to install the SSR and perform deep water intervention work much more efficiently than conventional approaches. The design uses best practices and multiple redundancies to ensure safety of personnel and protection of the environment, and includes multiple levels of reservoir containment. This phase of the project produced the conceptual design of the components needed for the SSR system. Challenges regarding the use of CT with a cost-effective vessel in deep and ultra-deep water were resolved. These challenges include the size and weight of the CT equipment in relation to vessel deck space, the effects of water depth and ocean currents on the equipment, and the need to have a riser for circulation. A detailed hazard identification review concluded that the hazards identified during this design phase have been effectively managed and mitigated. Industry experts, computer modeling, and experience from previous construction and installation of a prototype demonstrate that the SSR system can provide a safe and economical alternative to conventional deepwater well interventions in the Gulf of Mexico.

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EXECUTIVE SUMMARY

This report summarizes the information from the RPSEA project *Coiled Tubing Drilling and Intervention System Using a Cost Effective Vessel*. The objective of the project is to develop a practical, cost-effective downhole intervention system for deepwater satellite subsea wells with enhanced safety of personnel and protection for the environment. This system uses a modular, reusable Self Supporting Riser (SSR) and cost-effective vessels. The concept uses an SSR to extend the well casing up from the seafloor so that existing shallow water intervention systems, including CT and wireline, can be used in ultra-deep water.

Current methods for deepwater well intervention involve a mobile offshore drilling unit (MODU) or intervention vessel that has the drillpipe, tubing, wireline or electric line equipment for either circulation or non-circulation interventions. Using these types of vessels for intervention is very expensive, time consuming, and is dependent upon rig availability. Another method involves riserless intervention; however, this method can only be used on interventions that do not require circulation. The result of current deepwater intervention methods is that many deepwater subsea wells are abandoned after encountering downhole problems because the cost of a MODU is too high to justify workover.

The monetary impact of being able to do cost-effective interventions, without a MODU or intervention vessel, would open up another phase of deep water exploitation that does not exist today. Producing wells that are near or below the economic limit could be re-stimulated, or plugged back and re-completed in other zones. Coiled tubing drilling in many cases could be used to drill cost-effective laterals not being drained by the existing wellbore. Clean outs and workovers could be scheduled at a greater frequency, keeping more wells producing at optimum levels.

The high cost of deepwater workover makes development of marginal fields with oil reserves of less than 100 million barrels uneconomical. Intervention work that would increase the recovery factors of existing deepwater satellite wells, such as adding or repairing artificial lift and re-zoning, is frequently cost prohibitive.

This report presents a solution that enhances safety and environmental protection while meeting the economic goals. Key improvements in personnel safety and protection for the environment include placing fewer personnel in a hazardous location, improved response to named storm warnings, multiple levels of equipment for reservoir isolation and well control, and improved response for vessel emergencies.

The need to develop a safe, reliable, low cost solution for deepwater satellite well intervention led to the formation of this project. By using an SSR as enabling technology for cost-effective vessels and existing CT intervention capabilities, this system can reduce the cost of deepwater satellite well intervention by more than 50 percent.

The SSR system configuration is based upon previously developed technology, meetings with operators to define their requirements, and meetings with equipment and service providers to determine the equipment that is available today. The project team of industry professionals and subject matter experts designed the system to bridge the gap between need and availability, readily incorporate future expansion of capability, and consist almost entirely of field proven components. The system is specifically designed for the Gulf of Mexico (GoM), including hurricanes and loop currents, but would also work in other deep water regions.

The SSR is built from modular components that can be assembled in any combination to suit a particular application. The SSR connects directly to a subsea tree or wellhead. When the top of the SSR buoyancy module is more than 100 feet below the surface, it is immune to hurricane effects and is not classified as a hazard to maritime navigation. The SSR is designed for independent survival, regardless of sea state conditions and without needing to provide additional gas for the buoyancy modules. The SSR has multiple redundancy features that ensure personnel and equipment safety and reservoir containment.

A riser extension is used to extend the riser casing from the SSR up to the deck of the vessel. A motion isolation system (MIS) has been defined to isolate the SSR, which is fixed to the earth, from the vessel which is subject to motion, an maintain nearly constant tension, and optimize CT fatigue life.

The SSR can be quickly and safely abandoned and left unattended. In the event of a dynamic positioning (DP) system failure or other emergency, the reservoir is shut-in and the vessel is free to disconnect from the SSR and maneuver within seconds.

The system accommodates the primary difference between CT operations on land and CT operations in deep water by bridging the gap between the vessel and the seafloor, and by isolating the CT equipment from the effect of vessel motion. Extensive computer modeling and analysis determined the optimal tubing diameter to maximize fatigue life.

Today, deep water CT operations are only done by vessels such as a MODU, that are large enough to support the weight and size of the riser and CT system. The SSR allows the use of smaller, less costly vessels. Results of project work to date show that the vessel size and cost can be reduced still further by using a construction type vessel to install and recover the riser independently from downhole work. This allows any vessel equipped with CT or wireline equipment to work in water of any depth.

Safety of personnel and protection of the environment is shown by the results of a detailed hazard identification review and issue mitigation process. Practicality was shown by computer analysis and by wave tank testing and installation of a prototype SSR in 3,500 ft of water in the GoM that were completed prior to this project. This project justifies subsequent phases of the project which will provide the field test design, construction of necessary components, and a field test demonstration necessary for the commercialization of this technology.

This system provides a safe, reliable, low cost alternative approach for deep and ultra-deepwater satellite well intervention and improves the overall recovery of resources from existing fields. This approach is expected to lead to a new support industry, using smaller, cost-effective vessels to provide intervention services for deepwater and ultra-deepwater wells.

General

1.1 DOCUMENT SCOPE

This document summarizes the deliverables for the RPSEA Project 08121-1502 *Coiled Tubing Drilling and Intervention System Using a Cost Effective Vessel*.

The primary objective of this project phase was to investigate the feasibility of installing a Self Supporting riser (SSR) on an existing deepwater production tree or wellhead to enable intervention in the well in a safe and economical manner.

In this document, references made to the *SSR System* include the SSR, the CT technology for deepwater intervention, and vessels for riser installation and downhole intervention.

Eleven tasks were identified as the primary Phase 1 deliverables (Table 1). The information from these tasks is summarized in this document.

	Table 1: Project 1502 Task List and Status	
Task No.	**Task Title**	**Status / Comments**
1	Project Management Plan	Complete
2	Technology Status Assessment – For the Application of Coiled Tubing in Deepwater Subsea Wells. Based on extensive research by the University of Tulsa, Petroleum Abstracts.	Complete
3	Technology Transfer Plan	Complete
4	Routine Reports and Other Meetings	Complete
5	System Architecture and Design Basis Report – Developed the design basis and the core objectives for the SSR system.	Complete
6	System Conceptual Design and Analysis Report – Provide detailed design elements for the SSR System.	Complete
7	Operational Planning Report – Provide procedures for operations, maintenance, and contingencies, as well as conducting a reliability analysis and cost estimates.	Complete
8	Safety, Environmental, and HAZID – Addressed improvements in safety and environmental protection over prior practice and incorporated these improvements in the proposed design.	Complete
9	SSR System Component Design Report. Addresses riser / vessel interfaces that are not commercially available (RADS and MIS).	Complete
10	Vessel Requirements, Motion, and Deck Handling Study. Looking at the basic vessel requirements to handle installing and removing the riser and performing downhole intervention work.	Complete
11	Business Case and Commercialization Report	Complete

1.2 ACRONYMS

ABS	American Bureau of Shipping
BHTA	Bottom hole tool assembly
BOE	Barrels of oil equivalent
BOEMRE	Bureau of Ocean Energy Management, Regulation, and Enforcement
BOP	Blowout preventer
CT	Coiled tubing
DNV	Det Norske Veritas (Maritime accreditation)
DOE	Department of Energy
DP	Dynamic positioning
ESP	Electric submersible pump
FEED	Front-end engineering design
FMECA	Failure mode effects criticality analysis
FPSO	Floating production storage and offloading
GMC	General Marine Contractors
GoM	Gulf of Mexico
HAZID	Hazard identification (risk analysis)
HAZOP	Hazard operational analysis
HPU	Hydraulic power unit
HS&E	Health Safety and Environment
MEPS	Modular exploration production system
MIS	Motion isolation system
MODU	Mobile offshore drilling unit
MSDS	Material Safety Data Sheets
NDT	Non-destructive test
PPE	Personal protective equipment
RADS	Riser assembly deployment system
RFP	Request for Proposal
ROV	Remotely operated vehicle
RPSEA	Research Partnership to Secure Energy for America
SCSSV	Surface controlled subsurface safety valve
SSD	Seafloor shutoff device
SSR	Self Supporting riser
TLP	Tension leg platform
TVD	Total vertical depth
USCG	United States Coast Guard
VIV	Vortex induced vibration

1.3 UNITS OF MEASURE

B	Billion	MMBOE	Million barrels of oil equivalent
ft	Feet	MMbbl	Million barrels
in	Inch	MMBOPD	Million barrels of oil per day
lb	Pound	psi	Pounds per square inch
m	Meter	psia	Pounds per square inch absolute

1.4 DEFINITIONS

Buoyancy Module	As used in this report in regards to the SSR, buoyancy, buoyancy module, air can and gas can buoy all refer to the pressure equalized variable buoyancy elements used to support the SSR.
Deep water	Deep water is defined as water depths greater than 1,000 ft (305 m), and ultra-deep water is defined as water depths greater than 5,000 ft (1,524 m).
Dynamic Positioning	A computer controlled system that keeps a drillship / vessel in the proper position and heading and does not allow it to drift because of waves, currents, or wind. A ship can be considered to have six degrees of freedom in its motion, i.e., it can move in any of six axes. Three of these involve translation; surge (forward / astern), sway (starboard / port), heave (up / down), and the other three rotation; roll (rotation about surge axis), pitch (rotation about sway axis), and yaw (rotation about heave axis).
DP Equipment Class	DP 1 (Equipment Class 1) does not have full redundancy. Loss of position may occur in the event of a single fault. DP 2 (Equipment Class 2) has redundancy so that no single fault in an active system will cause the system to fail. Loss of position should not occur from a single fault of an active component or system such as generators, thruster, switchboards, remote controlled valves etc., but may occur after failure of a static component such as cables, pipes, manual valves etc. DP 2 vessels have two independent computer systems. Class 2 DP units with equipment class 2 should be used during operations where loss of position could cause personnel injury, pollution or damage with great economic consequences. DP 3 (Equipment Class 3) has to withstand fire or flood in any one compartment without the system failing. Loss of position should not occur from any single failure including a completely burnt fire sub-division or flooded watertight compartment. DP 3 vessels have two independent computer systems with a backup system.
Dry Tree	Subsea completion equipment (with valves, chokes and gauges) that is installed above the surface of the water.
Field	Field is defined as an area consisting of a single reservoir or multiple reservoirs grouped on, or related to, the same general geologic structural feature and/or stratigraphic trapping condition. There may be two or more reservoirs in a field that are separated vertically by intervening impervious strata or laterally by local geologic barriers or both.
Hook Load	The total force pulling down on the hook, typically the hook of a crane, lift line from a winch, or other lifting device.

Horizontal Tree	A tree design for subsea applications configured with the valves and flow-control equipment offset to the side so that the tree provides vertical access from the tree cap to the wellbore for drilling or other downhole work.
Proved Reserves	Proved Reserves are those quantities of hydrocarbons that can be estimated with reasonable certainty to be commercially recoverable from known reservoirs. These reserves have been drilled and evaluated and are generally in a producing or soon-to-be producing field.
Satellite Wells	Wells which are remote from the host platform. The hydrocarbons flow from the wells through flowlines, possibly to a gathering manifold, and then up to a production facility (FPSO or platform).
Swab Valve	The swab valve in a vertical or conventional tree is vertically aligned with the wellbore and isolates the product from the tree cap. It is used to control access to the wellbore when performing well intervention operations such as slickline, electric wireline, or CT.
Unproved Reserves	Unproved Reserves can be estimated with some certainty (drilled and evaluated) to be potentially recoverable, but there is as yet no commitment to develop the field.
Vertical Trees	A vertical or conventional tree has swab valves vertically aligned with the wellbore. Because the valves are too small to drill through them, the tree is installed after the well is drilled.
Wet Tree	Subsea completion equipment (with valves, chokes and gauges) that is installed underwater.
Wireline	A cable that is commonly used to raise and lower equipment in a well. Wireline operations can be either non-electric such as slickline or swabbing, or electric such as logging (evaluating well properties using a sonde, i.e., electrical, acoustical, and radioactive properties of the formation and fluids).
Workover	Any remedial operation on a completed well that is designed to maintain, restore, or improve production from a reservoir.

2 INTRODUCTION

2.1 CURRENT INDUSTRY DEEPWATER WELL INTERVENTION METHODS

Intervention for subsea, deepwater, satellite wells follows two standard approaches:

1. Intervention using a conventional MODU or intervention vessel (which is really a small MODU), to run a workover riser with a subsea blowout preventer (BOP). Intervention operations are done with a vessel supported riser via tubing and drillpipe, as well as wireline or electric line.
2. Riserless intervention where a subsea lubricator is connected to the subsea tree and wireline or electric line is run from the MODU or intervention vessel. This approach has no circulation from the vessel to the well and therefore has limited intervention capabilities.

One of the daunting challenges for ultra-deep water is the cost to re-enter existing deepwater wet wells (satellite wells), especially to do re-completions, stimulations, and other workovers. In many cases these wells are abandoned or suspended because of the costs to re-enter are too prohibitive using the conventional MODU approach. A high proportion of the cost is related to the high day rates for these drilling vessels and the limited rig availability.

The high cost of either choice, using a MODU for workover or abandoning reservoirs that could still produce, has limited the drilling of satellite wells that could extend the useful life of existing production systems such as SPARs and tension leg platforms.

2.2 ECONOMICS OF CONVENTIONAL APPROACHES TO DEEP WATER WELL INTERVENTION

Technological advances in the last two decades, particularly related to flow assurance, have allowed subsea wells to advance greater distances (up to 50 miles) from the host platform and to greater water depths (more than 10,000 ft) and include high pressure / high temperature completions. Prior to 1988, the deepest subsea completion was at 350 ft. Today, water depths of more than 10,000 ft can be reached.

There are billions of barrels of oil to find and produce in deepwater fields with recoverable reserves less than 100 million barrels (MMbbl). Because of the high costs and time associated with deepwater subsea completions, oil companies using conventional approaches consider these fields to be uneconomical so they are not developed.

Reports from the Department of Interior (published in 2009) project the total Gulf of Mexico (GoM) production to exceed 1.7 million barrels of oil per day (MMBOPD) and if the industry announced discoveries are realized, the potential could reach 2.1 MMBOPD. These reports were published prior to the moratorium and new regulations issued for the GoM, so the estimated volumes will be impacted.

The following figures are from the Department of Interior reports (detailed reference is in Appendix A):

- Figure 1 shows the number of fields and field size ranges from a worldwide perspective.
- Figure 2 shows the estimated million barrels of oil equivalent (MMBOE) of proved deepwater fields in the GoM.
- Figure 3 shows the active leases by water depth in the GoM.

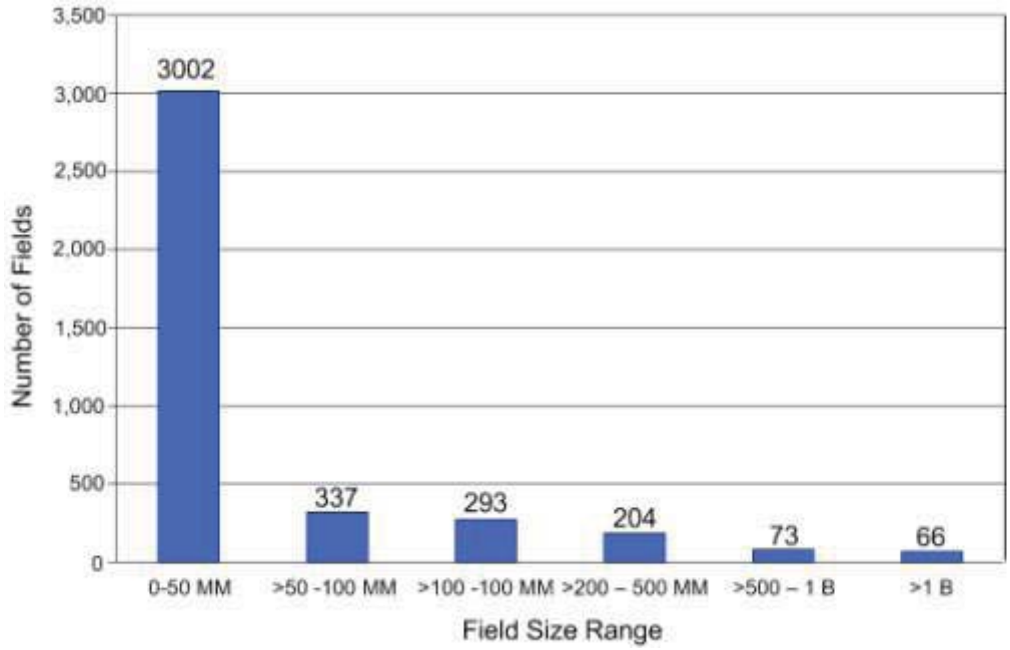

Figure 1
World Wide Number of Deepwater Fields and Size Range

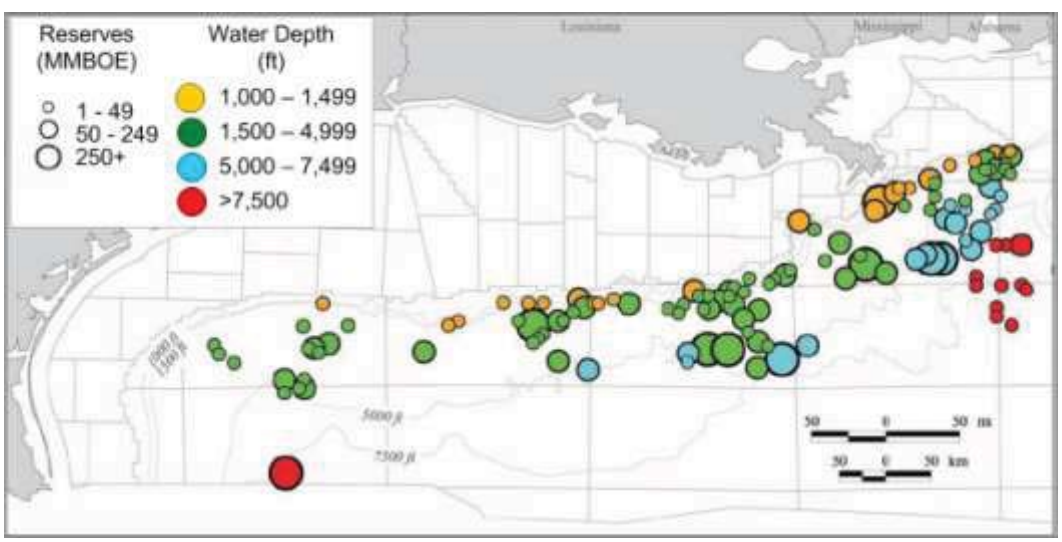

Figure 2
Estimated Volumes (MMBOE) of Proved Fields in the GoM

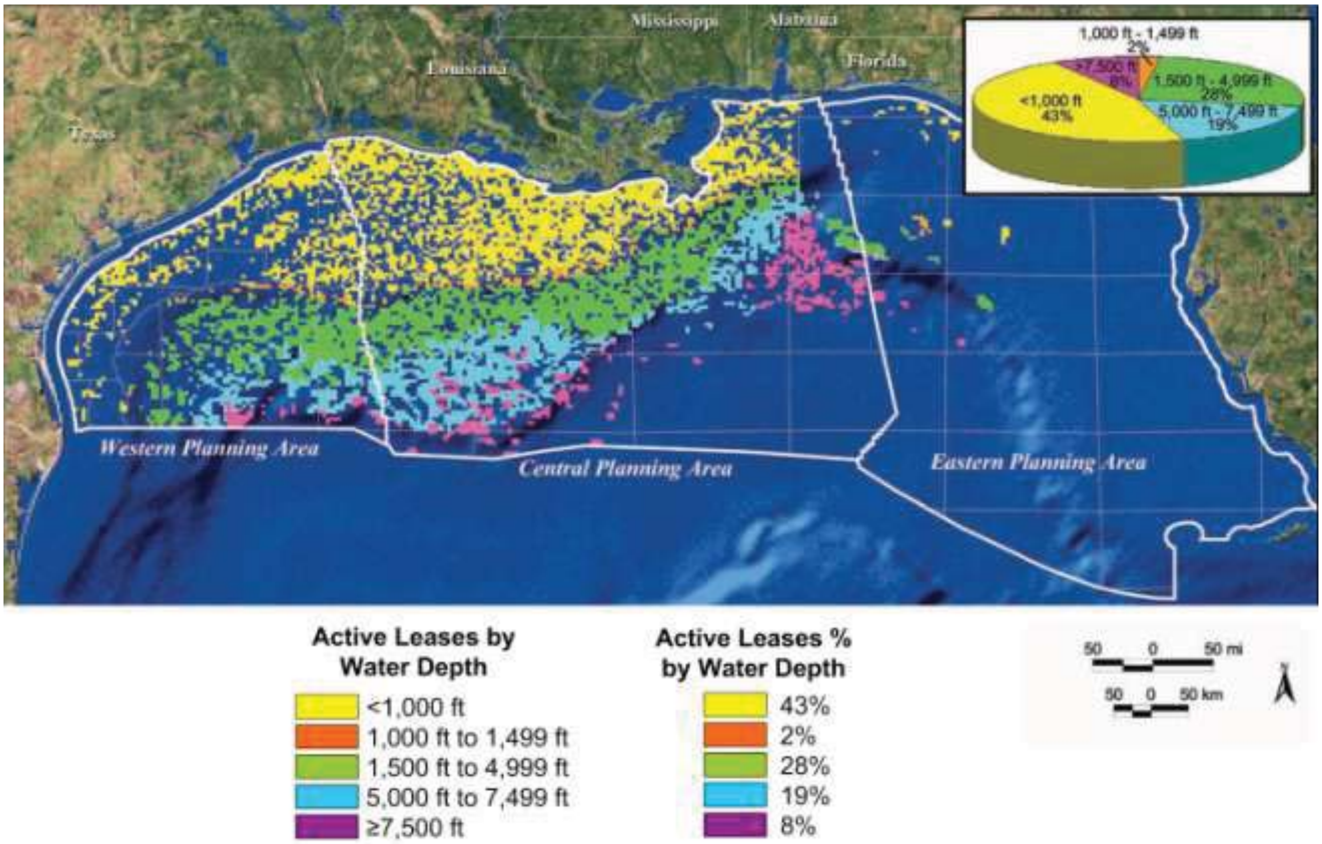

Figure 3
Active leases in the GoM by Water Depth

According to the Department of Interior Records, as of 2009 there were 1,006 satellite wells in the GoM in water depths greater than 1000 feet, and the majority of these wells have vertical trees. From this total number, 157 of these wells have been shut-in and 30 of these wells have been abandoned. Appendix A contains the data on current deepwater GoM projects and future projections.

As the number of deepwater subsea wells increase, so does the need for intervention work, whether it is a downhole equipment failure, a buildup of sand, plugged perforations, need for stimulation, adding or repairing artificial lift pumps, and/or the need to plug back and side track to a new zone. Operators realize that intervention is key to improving the recovery factors of subsea wells. Even with improved technology, the cost and time expenditures of using conventional intervention approaches continue to be obstacles.

A cost effective, fast, and safe solution for deepwater satellite well intervention, as defined in this document, will enable the exploration, testing, completion, production, and intervention of these deepwater marginal fields to potentially add billions of BOE for US domestic production.

2.3 CURRENT USES FOR COILED TUBING

While many workovers can be conducted with wireline or slick line, most interventions and re-completions require circulation of fluids from the surface. Circulation requires a riser to isolate the fluids from the environment. Using an SSR and CT offers a safe, practical, economically feasible approach to circulation.

Coiled tubing has evolved over the last 30 years and has become a major option for intervention operations on land instead of using conventional drilling rigs. Offshore, CT applications have been limited to shallow water, dry tree wells. For deepwater wells, CT intervention is rarely used, since it requires using a MODU, intervention vessel, or a stationary production platform to support the weight of the riser needed to isolate circulation fluids from the environment. Smaller, more cost effective vessels cannot support the riser. This report presents use of a Self Supporting Riser to solve this problem

2.4 SELF SUPPORTING RISER SYSTEM SOLUTION

The solution proposed in this document is based on using a patented SSR that connects directly to a subsea tree or wellhead. The modular, reusable SSR in effect brings the well casing up from the sea floor so that existing shallow water intervention systems can be used in any water depth. This solution proposes using cost-effective vessels to install the SSR and to do the intervention work with CT equipment. This method accommodates workover interventions that require either wire line or CT with circulation.

The SSR system (which includes the cost-effective vessels, CT equipment, and the SSR), provides companies with a safe and affordable way to complete, re-enter, and maintain deepwater subsea wells. This system will facilitate improved resource recovery from existing satellite wells and make it practical to develop marginal reservoirs that would otherwise not meet economic hurdles. The overall cost to deploy and operate the SSR system is less than half the projected cost of a MODU. This cost-effective approach breaks the paradigm for using costly MODUs and leads to another support industry, using smaller, cost-effective vessels, to provide intervention services for deepwater and ultra-deepwater wells. A depiction of the SSR system with an intervention vessel is shown in Figure 4.

Safety aspects of the SSR approach include placing fewer personnel at risk. Current estimates show a reduction of 60 to 80 percent in the number of people working at the well site as compared to the number onboard a MODU. A comparable reduction in active equipment onboard the vessel further simplifies the overall system and reduces the risk of collateral damage that can result from failure of any equipment onboard the vessel.

In addition to the reservoir isolation provisions afforded by the MODU BOP at the seafloor, the proposed approach includes a full function suite of CT BOP and associated well control equipment on deck, plus near surface shear and seal provisions just below a near surface disconnection interface between the riser and the vessel mounted equipment.

The near surface disconnection feature allows the vessel to depart without first recovering the riser. This reduces the response time for a named storm warning from days to hours, which consequently reduces the number of unnecessary withdraw and reenter cycles, each of which presents risk.

The SSR itself is designed with safety features that include multiple buoyancy chambers to support the riser. Each chamber has a steel hull to resist marine hazards, a liner that provides a second barrier between seawater and the buoyancy gas. Other safety features include dropped object protection and pressure equalization to reduce the stresses on the buoyancy module hull.

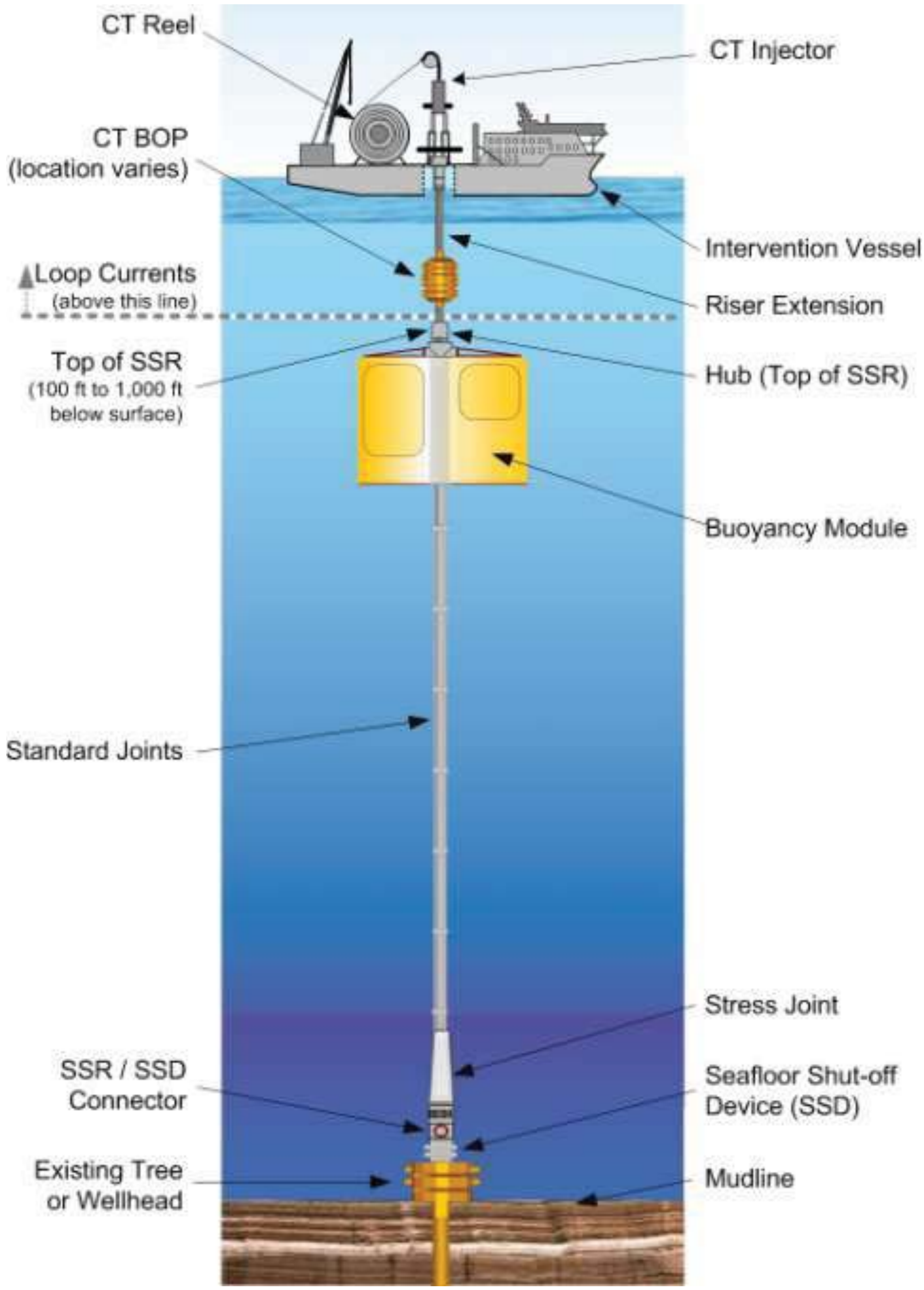

Figure 4
Overview of SSR system with Intervention Vessel

3 PROJECT INITIATION AND OBJECTIVES

RPSEA and DeepStar identified the high cost of well intervention as one of the primary deep water challenges. A request for proposal was issued and a contract was awarded to Nautilus International to bring the project from conceptual feasibility, with the intent that development would proceed through design and construction of the necessary components and conclude with a field test demonstration. The project is co-funded by RPSEA, contract number 08121-1502.

3.1 PROJECT OBJECTIVES

A primary objective of this project is to provide the basis for a detailed design and feasibility analysis of the SSR system for downhole work in deepwater GoM satellite wells. The focus of this project is the GoM but the project has world-wide applications. The detailed objectives include:

- Work in Gulf Stream conditions and in water depths to 10,000 ft.
- Provide a highly reliable system that enhances safety for personnel.
- Improve environmental safeguards including provisions for reservoir containment.
- Able to complete a wide range of downhole tasks.
- Use for both wireline (no circulation) and CT (circulation).
    - Establish availability of a large selection of suitable low cost vessels.
    - Excellent weather availability.
    - Acceptable vessel motions.
    - Adequate deck space and storage for consumables.
    - Suitable dynamic positioning (DP) capabilities.
- Provide services at less than half the cost of using a MODU.
- Use existing CT service contractors.
- Use with contractor’s standard equipment.
- Establish hardware and vessel availability for a demonstration.
- Fully operable system available one year after demonstration.
- Make the riser installation and recovery is independent of CT work to provide improved flexibility and lower costs.
- Develop a modular system with reusable hardware that is readily adaptable to any water depth and water conditions.

3.2 PROJECT TEAM

A team of highly competent industry professionals and subject matter experts contributed throughout this project. All CT service providers in the GoM and workover vessel companies were contacted to provide input. The project team is shown in Figure 5.

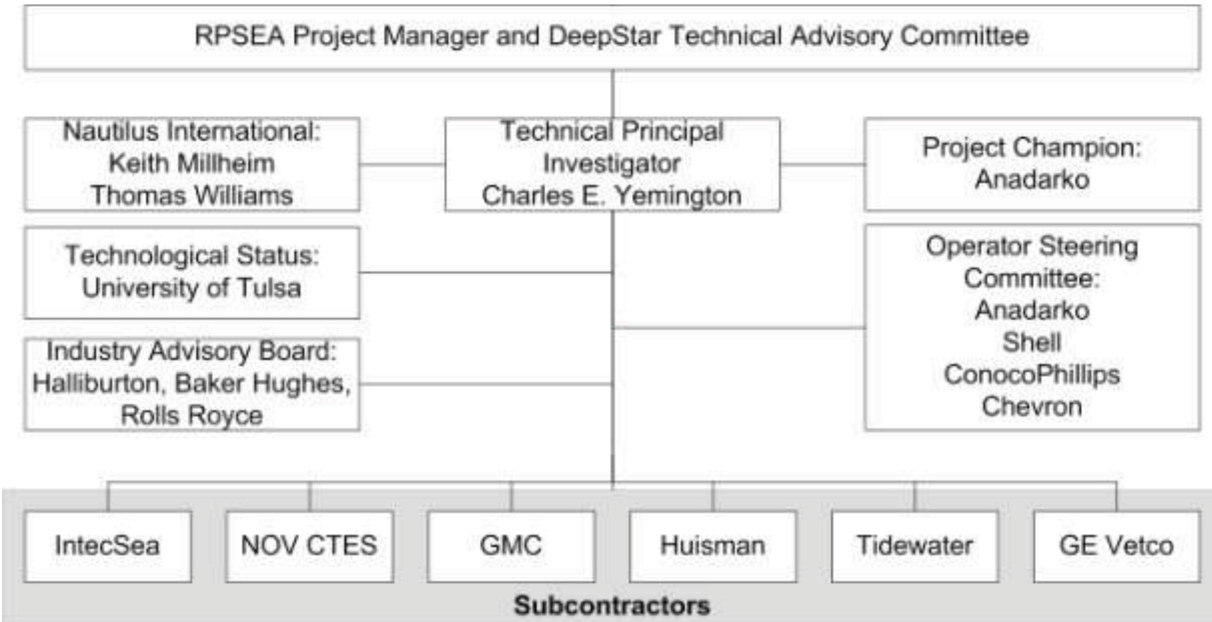

Figure 5
Project 1502 Team Members

Subcontractor area of expertise:

NOV CTES	CT equipment specification and modeling of operations
IntecSea	Riser design and analysis
GMC	Vessels, equipment, and reliability analysis
GE Vetco	Subsea equipment
Tidewater	Vessel configuration and cost estimates
Huisman	Motion isolation system, riser extension and stabilization

3.3 PROJECT PHASES

Phase 1 is the conceptual design and design verification of the SSR system. This phase looked at five major design considerations for the *SSR System*:

1. Capability of CT to operate in the GoM deepwater environment (physical properties of the CT string for various pressures, depths, and internal diameters).
2. The 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 CT could be safely cut in the event of a vessel drive-off or some other event requiring a quick departure from the well.
4. The feasibility of using a smaller, non-MODU vessel to install and remove the SSR and to support the intervention activities.

5. The cost effectiveness for using the SSR for intervention activities in the GoM.

Phase 1 includes:

- Component analysis.
- Dynamic analysis and simulations of the system.
- Simulation with the proposed CT / vessel system for downhole functions such as drilling, circulating, and stimulation.
- Health, Safety, and Environment study, cost estimate, and risk analysis for the second phase.
- A commercialization plan.

The commercialization plan includes a Phase 2 demonstration project, which will first require the detailed design of the SSR system, the engagement of the various service and contractor providers, and the construction of the components necessary to carry out a series of interventions (not drilling) on a deepwater well in the GoM. During this phase well candidates and operating company involvements will be incorporated in the project.

The next step will be the first field test on a deepwater well where a series of well interventions will be performed. These could include a range of activities such as circulation of fluids, setting downhole equipment, and other non-drilling activities, including plugging and abandonment. HAZID and HAZOP reviews will be held regularly throughout the program to help ensure that all designs and procedures meet rigorous standards for personnel safety and protection of the environment.

Commercialization of the SSR system will also include the demonstration of drilling a sidetrack wellbore, and possibly multi-laterals, using the SSR system.

4 INDUSTRY NEEDS AND SSR SYSTEM DESIGN ELEMENTS

The SSR system must provide operators with a safe, cost-effective, routine intervention capability for deepwater satellite wells. This section describes the criteria used to determine the SSR system architecture and the detailed design elements for the SSR, CT equipment, and low-cost, non-MODU vessels for installation of the SSR and intervention work.

4.1 SSR PROTOTYPE

Overall performance of the SSR is known from Anadarko Petroleum's Modular Exploration and Production System (MEPS) project that included computer modeling, wave tank testing, and installation of a prototype SSR on a simulated wellhead in 3,500 ft of water in the GoM in 2006. The project members included contractors working with regulators and operators. Figure 6 shows the prototype buoyancy module being installed and Figure 7 shows the module after two years under water.

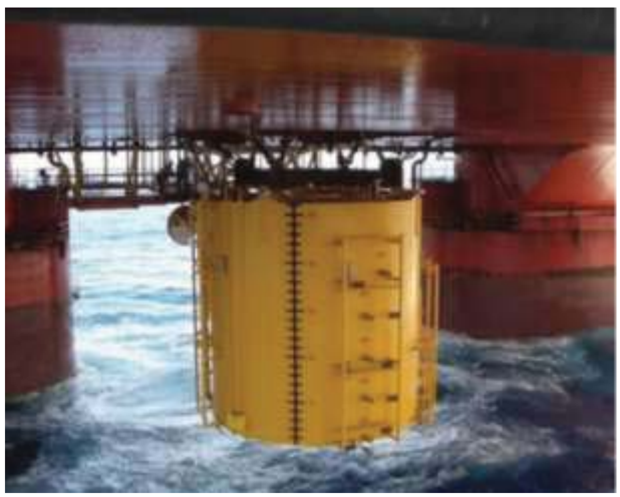

Figure 6
Buoyancy Module Prototype Being Installed

Figure 7
Buoyancy Module Prototype After Two Years Under Water

4.2 INDUSTRY DESIGN CRITERIA

The criteria defined by the industry advisory committee were used to develop the SSR system architecture and design basis. The system is designed to meet the highest standards and is readily expandable to accommodate a wide range of other tasks and to meet the extreme demands of depth, pressure, and flows. The range of SSR system application criteria is:

- Water depths of 500 ft to 10,000 ft in central GoM, optimized for 5,000 ft to 6,500 ft.
- Total vertical depth (TVD) from 5,000 ft to 23,000 ft below the seafloor, suitable for future extension to measured depth of 35,000 ft below the seafloor.
- Pressure rating of 10,000 psi, suitable for future extension to 15,000 psi or higher.
- Suitable for both CT and wireline intervention plans.
- All installation and intervention work can be done with small, readily available vessels, without having to utilize a MODU.
- Total intervention cost at least 50% less than for a MODU.
- Wellbore access through existing horizontal trees, vertical trees, and wellheads.
- Applicable to both oil and gas wells.
- Intervention system suitable for returns from reservoir.
- Configured for best reasonable availability using small vessels in central GoM.
- Basic system designed exclusively with components available in 2011.

Performance is to be optimized for work 18,000 feet below the mudline in the Neogene (Paleogene) Upper Tertiary Trend (Figure 8). The design is based on using 2-3/8 in. tubing in a 5-1/2 in. or 6-5/8 in. riser, in 5,000 to 6,500 foot water depth, for a total tubing length of 24,000 ft.

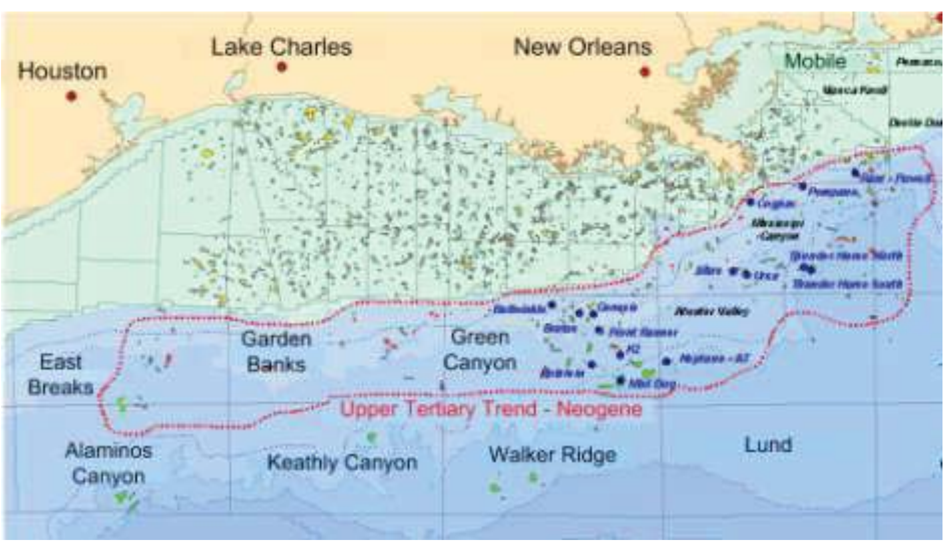

Figure 8
Gulf of Mexico Area where Design is to be Optimized

The contractors and the industry advisory board listed and prioritized downhole functions such as: mechanical work, fishing, sliding sleeves, bridge plug, logging, perforating, set / install packers, plug and abandonment, milling, acid stimulation or acid washing, profile modification (cement or gel squeeze), frac jobs, well kill, re-completions, drilling and deepening of existing wellbores, well testing, ESP replacement, and surface controlled subsurface safety valve (SCSSV) replacement.

The design requirements for the SSR, and the CT equipment emphasize using commercially available components. High-level design has been completed for SSR / vessel interface equipment (see Sections 8.1 and 8.2) that is not commercially available. The detailed design specification for these components will be prepared subsequent to Phase 1.

The information gathered from the MEPS project, along with the expertise from the entire project team, contributed to the SSR system architecture, design elements, and feasibility analysis.

4.3 SELF SUPPORTING RISER DESIGN GOALS

One of the major goals of the design and conceptual feasibility work was to preserve the following SSR advantages:

- The SSR does not require support from a vessel. The SSR can be left unattended following installation, and after completion or interruption of downhole work.
- Different vessels can be used for riser installation and downhole intervention, with one vessel optimized for construction work and the other optimized for well intervention. Benefits of this include:
    - Scheduling flexibility and system availability are improved.
    - Contractor coordination is simplified by isolating riser installation, essentially a construction task, from downhole operations.
    - The installation vessel does not require classification for flammable gasses and its efficiency is not handicapped by provisions to accommodate returns.
    - The installation vessel does not require provisions for intervention equipment and consumables.
    - An installation vessel with minimum crew can install and recover the riser.
    - The intervention vessel does not need a large moonpool or deck space to accommodate the riser.
    - The need for a supply boat is usually eliminated.
    - It is not necessary to exchange crews or have one crew stand by while another crew works.
    - The total cost of contractor equipment is reduced significantly.
- Variable riser buoyancy can be used to significantly reduce the hookload during installation and recovery of the riser. A lesser crane rating improves availability and reduces vessel cost.
- Use of the SSR allows existing shallow water, riserless intervention systems to be used in deep water and ultra-deep water.
- The downhole intervention vessel can disconnect and maneuver almost immediately in the event of a vessel emergency.

- The intervention vessel is free for a planned departure from the wellsite within 4 to 6 hours. This allows the vessel to work longer in the event of a closing weather window or threat of a named storm, so availability is improved with fewer contingency interruptions. This improves safety by reducing the number of times it is necessary to connect and reenter the well.
- The intervention vessel can motor to the host platform or move away from the seafloor infrastructure for transfer of equipment or personnel without significant schedule impact because there is no need to trip the riser.

5 SELF SUPPORTING RISER COMPONENTS

The major components of the SSR are discussed in this section, beginning at the bottom of the riser.

5.1 SSR OVERALL DESIGN PARAMETERS

The SSR and all its components are designed to meet the latest regulatory requirements, including those of the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE), as well as API standards, industry standards, and recommended practices. The overall system is suitable to qualify for a certificate of operability from ABS or DNV.

The primary environmental load factor for the SSR is sea currents. The design and feasibility of the SSR focused on extended, independent survival under design current conditions without supplying any additional gas to maintain the buoyancy modules, and without inspection or other intervention. Other loads are primarily from interfaces to the vessel and the weight of equipment that sets on or hangs below the buoyancy modules.

The riser is rated for internal pressure of 10,000 psi and suitable for hydrostatic testing to at least 1.25 times rated pressure.

Allowable riser tension during operations is substantially greater than required for survival, so there is margin for loads on the riser to vary for the different stages of operations.

The design includes allowance for two years of marine growth at a depth of 100 ft in the central GoM.

5.2 TREE INTERFACE AND SEAFLOOR SHUT-OFF DEVICE

The SSD is the lowest / bottom point of the SSR and connects to either a vertical or horizontal tree or to the wellhead directly. The main purpose of the SSD is to isolate the reservoir. In case of an emergency it can shear the CT, wireline, or tools attached to the tubing as it closes.

Examples of a vertical and horizontal tree are shown in Figure 9. The primary distinction is that a horizontal tree extends the well casing up through the tree to crown plugs, while the conventional or vertical tree has valves in the vertical column above the well.

Figure 9
Vertical Tree (Conventional) – Left
Horizontal Tree - Right

An electric-hydraulic umbilical connects the intervention vessel with the SSD for control of the shear and seal functions of the SSD and control of the tree from the vessel. All functions of the SSD are ROV-operable in case communication via the umbilical is disrupted. The SSD has surface controlled energy stored in accumulators to ensure close, open, and re-close cycles of all functions.

A connector from the original tree running tool or completion riser may be used if available. The connection between the tree and SSD provides:

- Structural anchoring of the SSR.
- Continuity of the pressure boundary.
- Alignment of the intervention tubing with the production tubing in the well.

In normal operation, the SSD is controlled electrically and hydraulically from the surface via the control umbilical. However, all SSD functions have interfaces for ROV override. This provides redundant controls for the shear and seal functions, provides a method to recharge the energy stored in the accumulators, and provides access for direct injection into the wellbore. The SSD has an umbilical junction box, and an ROV can install an umbilical jumper between the junction box and the tree.

To ensure against unplanned release of the SSR from the tree, connectors for both the top and the bottom of the SSD are operable only by ROV (no remote operation). These connectors are designed to not release under tension. The SSD is illustrated conceptually in Figure 10.

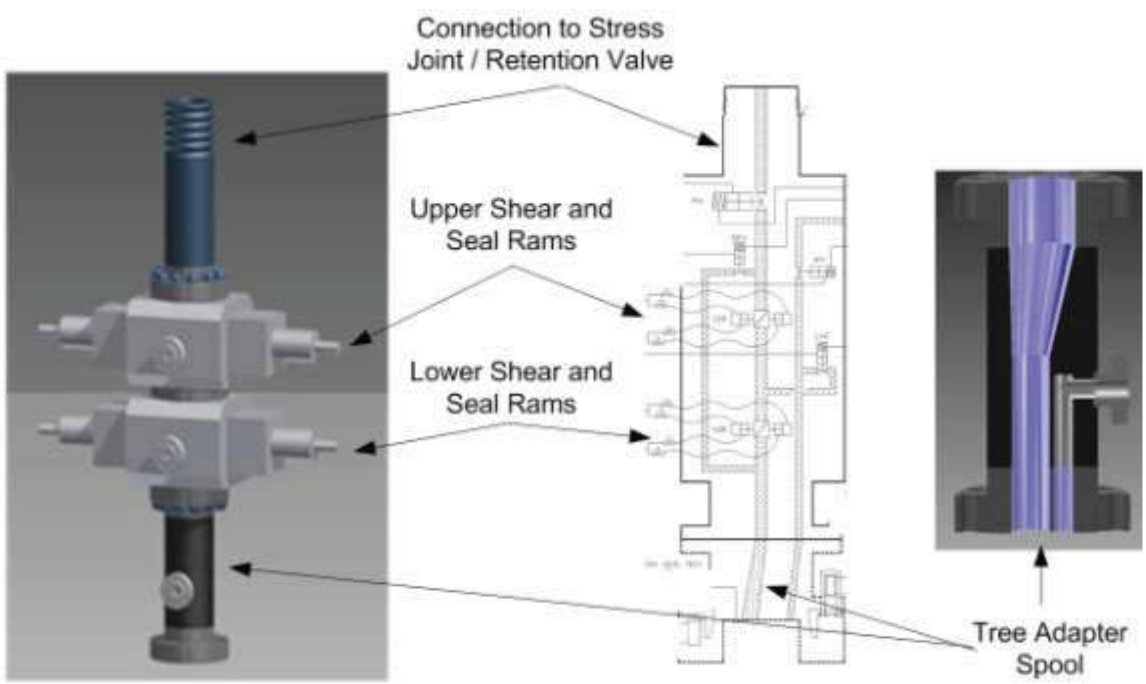

Figure 10
SSD Illustration, Schematic, and Tree Adaptor Spool

The upper ram connects to a crossover joint with an upward facing connector hub that connects the SSD to the SSR stress joint / retention valve assembly.

An adaptor spool connects the bottom of the lower shear ram to the mandrel on top of the tree. The adaptor spool aligns the CT with the production tubing of any tree. As shown in Figure 10, the spool diverts the annulus line 90º to a 2-1/16 in. outlet located on the side of the adaptor. The outlet can be routed through a series of valves to allow access to the annulus monitor line and / or crossover into the production wellbore via the shear rams.

5.3 STRESS JOINT, RETENTION VALVE, AND CONNECTOR

The stress joint provides the transition between the flexibility of the SSR joints and the stiffness of the tree interface equipment. Different stress joints may be used, such as a drill collar (when the top of the SSR is below strong surface currents), a stepped stress joint or a tapered stress joint.

The SSR can be removed while the SSD stays in place to provide reservoir isolation. This is accomplished with a connector between the upward facing hub on the SSD and the SSR stress joint. This connector is only operable via ROV intervention to prevent inadvertent release and is designed not to release under tension.

The stress joint assembly has a retention valve that prevents fluid loss from the SSR if the riser is removed while the SSD is left on the tree to isolate the reservoir. The retention valve also has an indicator to show the open / close valve status.

The stress joint, retention valve, and connector assembly (Figure 11) all have an internal pressure rating of at least 10,000 psi at 1.5 times the maximum bending moment and tension load that may be experienced in extreme operating conditions.

The connector and retention valve do not depend on energy from the accumulators, and cannot be operated via the umbilical to the surface. This enhances safety by reducing the possibility of in advertent operation.

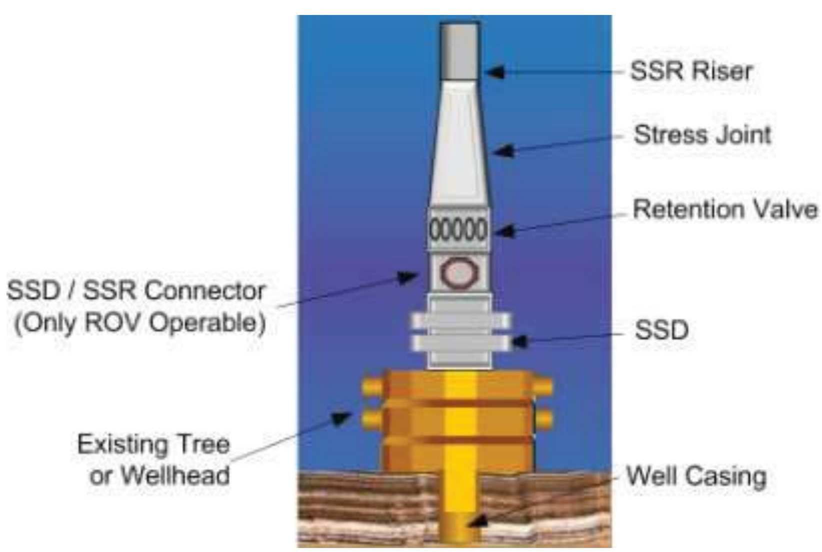

Figure 11
Stress Joint, Retention Valve, and ROV Operable Connector

5.4 STANDARD JOINTS

Riser casing for the baseline configuration is 6-5/8 inch drillpipe with nominal internal diameter of 5.761 to 5.965 inches. Larger diameter drillpipe or steel casing may be used as required. Regardless of the diameter and thickness of the joints, premium gas tight threads (suitable for 10,000 psi under maximum bending) are used to connect the joints.

The necessary number and type of joints can be assembled to suit a particular application and depth.

5.5 BUOYANCY MODULES

The elevation and number of buoyancy modules can be selected to suit a particular application. The uppermost buoyancy module is set at least 100 ft below the surface at low tide so that, when left unattended or following an emergency disconnect, the SSR is not considered to be a hazard to maritime navigation and it is not necessary to attach a warning buoy.

Figure 12 depicts a buoyancy module.

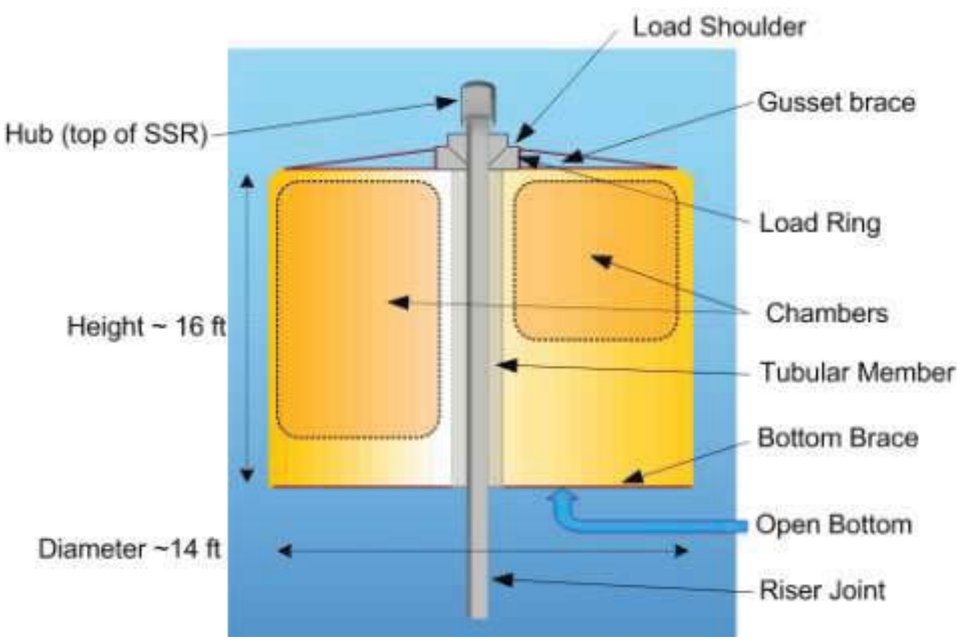

Figure 12
Buoyancy module and Riser Joints

The modules are pressure-equalized gas can cylinders with an outer diameter of 14 ft. Each buoyancy module has multiple chambers so that unintentional flooding of a chamber does not impair the function of the riser. Multiple buoyancy modules are used, each having multiple chambers, so that flooding of any one chamber would not compromise the overall function and survival of the riser.

The modules are designed maximize the ratio of buoyancy to displacement, which helps reduce the drag from the ocean current. The top and outer hull of the module are constructed from steel to prevent damage from dropped objects and other marine hazards, while lighter weight materials, such as fiberglass, may be used for internal bulkheads.

External guide sleeves on the modules are designed to engage with the guide rails that extend through the moonpool of the installation and recovery vessel. An ROV is used to attach wires that align the guide sleeves to the rails for module recovery.

Conduits or shields are used to protect the piping, umbilicals, and cable runs. Valves, controls, and other accessories are located on the underside of the buoy, where they are least exposed to dropped objects and underwater hazards.

Coatings and markings are suitable for extended underwater applications. Both the inside and the outside surfaces of the buoyancy modules are coated for corrosion protection. Anodes are located on the top and bottom surfaces of the module.

Each module has a vertical tubular member from top to bottom on the vertical axis of the module. The tubular member continues the gas tight pressure boundary from the top of the hull down to the bottom. A load ring on the top of the hull provides the load path for the buoyancy. The load ring bears against a shoulder on the riser joint. A split collar may be used between the shoulder on the joint and the load ring on the buoy. The split collar may have instruments to measure the net buoyancy of the module.

The riser joint is inserted through the module from the top. To facilitate threading to joints above and below the buoy, the joint is free to rotate with respect to the buoy when not seated on the load ring. The bottom perimeter of the hull is braced to the vertical tubular member to react to forces due to current drag, inclination of the buoy, and overturning moments due to loads above the buoy. The lower end of the vertical tubular member extends this load path to the joint that passes through the tubular.

5.6 RISER JOINTS THROUGH BUOYANCY MODULES

The buoyancy module joints provide keel joint functions to extend the fatigue life at the base of the module. The buoyancy module joint has a load shoulder to suit the load ring (or a split collar adapter) that is on the top of the buoy hull.

Instrumentation to measure buoyancy of each buoy and / or tension below each buoy provides data either by ROV video or by real-time display at the surface. Buoyancy instrumentation is integral to the joint (or to the split collar adapter) between the buoy and the load shoulder of the joint. Tension instrumentation can be integral to the joint through the buoy or on the joint immediately below the buoy. As a minimum, riser tension below the lowest buoy is available for real-time display at the surface either from acoustic data or through an umbilical.

6 RISER EXTENSION

The riser extension extends the riser casing up to the deck of the vessel from the SSR for intervention work that requires circulation. A motion isolation system (MIS) is required because the riser is fixed to the earth and the vessel is subject to movements. The riser extension is structurally designed to withstand the tension and bending loads between the vessel and SSR. The riser extension consists of two segments to facilitate maintenance of active components by the intervention vessel (Figure 13):

- The emergency disconnection segment contains the active components for sealing the top of the SSR, shearing the tubing, and releasing the vessel from the SSR.
- The structural casing segment of the riser extension extends the riser casing up through the intervention vessel moonpool for connection to the MIS and the CT injector.

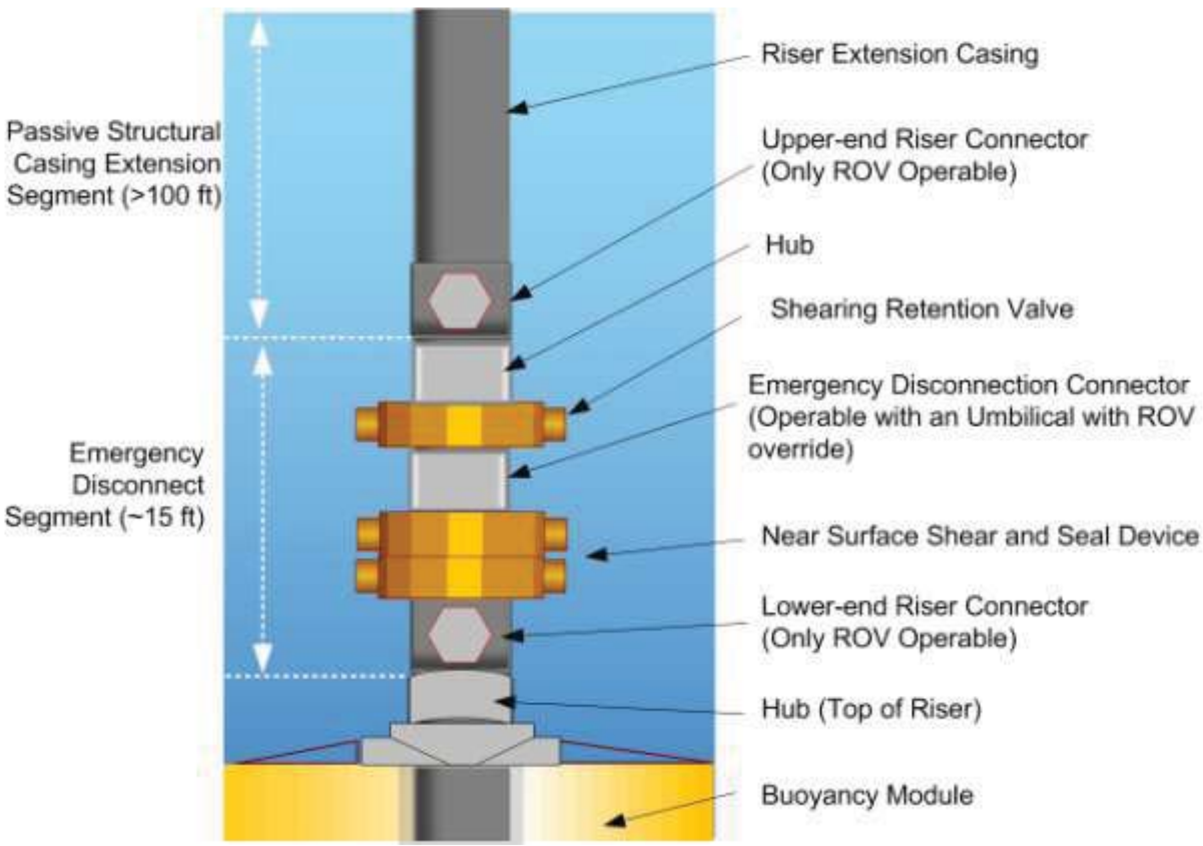

Figure 13
Typical Riser Extension Components

6.1 DISCONNECTION SEGMENT OF RISER EXTENSION

The disconnection segment can be assembled and tested onshore, and then installed on the SSR by an intervention vessel. All functions have status indicators for ROV readouts and interfaces for ROV override. The active components include:

- The near-surface shear and seal device.
- The disconnection-connector for routine or emergency disconnection.
- Connectors for engaging the top of the SSR and the bottom of the structural casing segment of the riser extension.

The connector on the lower end of the emergency segment is a ROV operable connector that attaches with the hub on top of the SSR.

The near-surface shear and seal device is above the lower-end connector. The near-surface shear and seal device has redundant controls and stored energy to rapidly close and seal the top of the SSR and isolate the contents of the riser. If tubing is present, the device shears the tubing immediately below the disconnection-connector.

The emergency disconnection-connector is above the near-surface shear and seal device. This is the only connector in the SSR designed to release under tension and bending.

A shearing retention valve is located immediately above the disconnection-connector. The retention valve prevents loss of static or pumped fluid from the riser extension following disconnection from the SSR. Since it can also shear tubing, it provides safety backup to the near-surface shear and seal device.

The disconnection segment of the riser extension terminates in an upward looking hub that engages with the connector on the lower end of the structural casing segment of the riser extension.

6.2 STRUCTURAL CASING SEGMENT OF RISER EXTENSION

The structural casing segment of the riser extension can be *wet parked* or hung off the SSR buoyancy module after assembly by the SSR installation vessel. In this case, the CT intervention vessel relocates the structural casing segment from the wet park location and connects it above the disconnection segment.

The lower end of the structural casing segment of the riser extension is the connector that joins with the hub on top of the disconnection segment. An ROV removable plug is provided to protect the seals and connection mechanism from corrosion and marine growth while wet parked.

The upper end of the structural casing segment connects to the motion isolation system, and has tension sensing instruments that provide feedback data back to the motion isolation system.

7 UMBILICALS

There are three main umbilicals for the SSR system (Figure 14):

1. An umbilical runs from the vessel to the tree and SSD. Functions of this umbilical include control of the tree, cycling of the SSD, and recharging the accumulators that provide the stored energy to operate the SSD. It may also carry instrumentation data. This umbilical can be installed with the SSR from the installation vessel, or run from a reel on the CT intervention vessel. Before abandoning the SSR, the upper end of the umbilical will be capped to protect it from corrosion and marine growth. The vessel end of this umbilical includes a termination assembly for quick release and abandonment in case of emergency disconnect.
2. An umbilical runs from the vessel to the near-surface shear and seal device of the riser extension. The umbilical to the near-surface shear and seal device is not secured to the segment of the riser extension that remains with the vessel following emergency disconnection. Functions of this umbilical are primarily to recharge stored energy and to initiate closure of the near-surface shear and seal device.

   This umbilical may also connect to an umbilical on the SSR to ballast and de-ballast buoys and to carry buoyancy and tension data to the surface. The vessel end of this umbilical is terminated for quick release from the vessel following an emergency disconnection.

3. An umbilical from the vessel to the emergency disconnection connector and shearing retention valve of the riser extension. This umbilical may be secured to the segment of the riser extension that remains with the vessel following emergency disconnection. Functions of this umbilical include cycling the emergency disconnection connector and the shearing retention valve above the connector.

As shown in Figure 14, the three umbilicals are mechanically isolated.

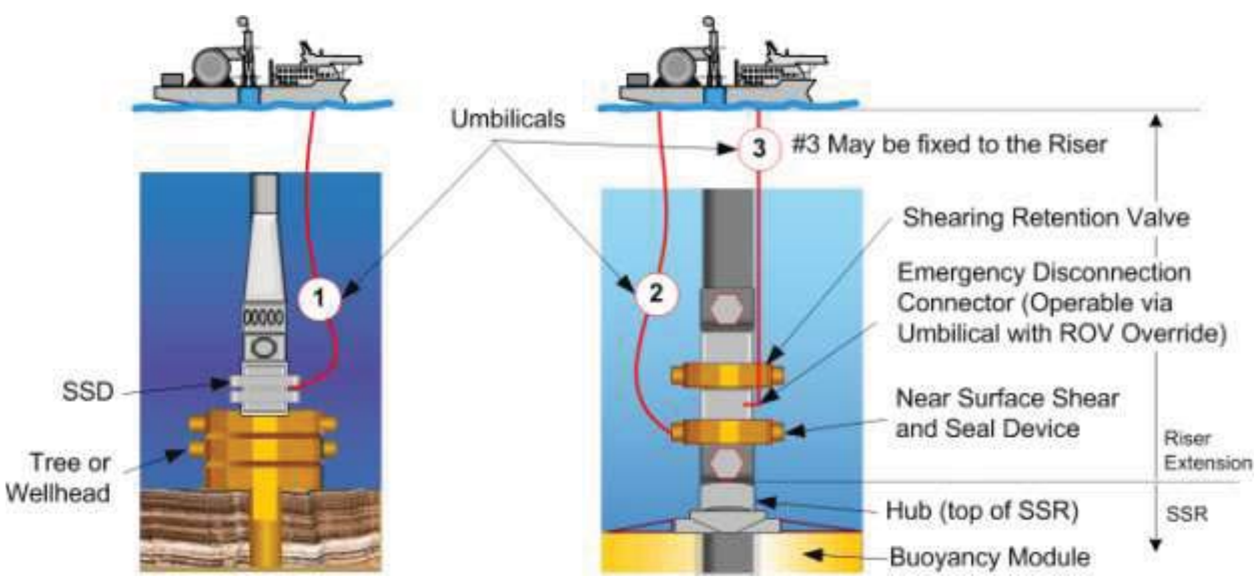

Figure 14
Umbilicals in the SSR System

8 DECK EQUIPMENT AND INTERFACES

The riser assembly and deployment system (RADS) for the SSR installation vessel and the motion isolation system (MIS) for the CT intervention vessel are integrated systems that can be lifted onto a vessel and set over a moonpool. The systems are designed to be built from available, field-proven components. Detailed designs for the RADS and MIS are not part of this phase; the detailed designs will be completed as objectives of Phase 2, if accepted.

Safety, reliability, and efficiency (in that order) are top priorities in the design of the RADS and MIS. Minimizing deck space, deck load, and overall vessel size are also important design considerations.

8.1 RISER ASSEMBLY AND DEPLOYMENT SYSTEM

The RADS is a tooling package that can be mobilized to prepare a relatively small vessel for riser installation. All functions needed to run and recover the riser, including the SSD, the stress joint assembly, the various connectors, and the buoys are integrated into the RADS. The RADS (shown schematically in Figure 15) includes the functions of tongs, slips, split moonpool cover, and elevated work platform, and controls the motion of buoys as they are lowered through the moonpool. Winch wires from the RADS or a crane line are used to take the weight of suspended joints off of the slips and lower the suspended joints after each new joint is connected.

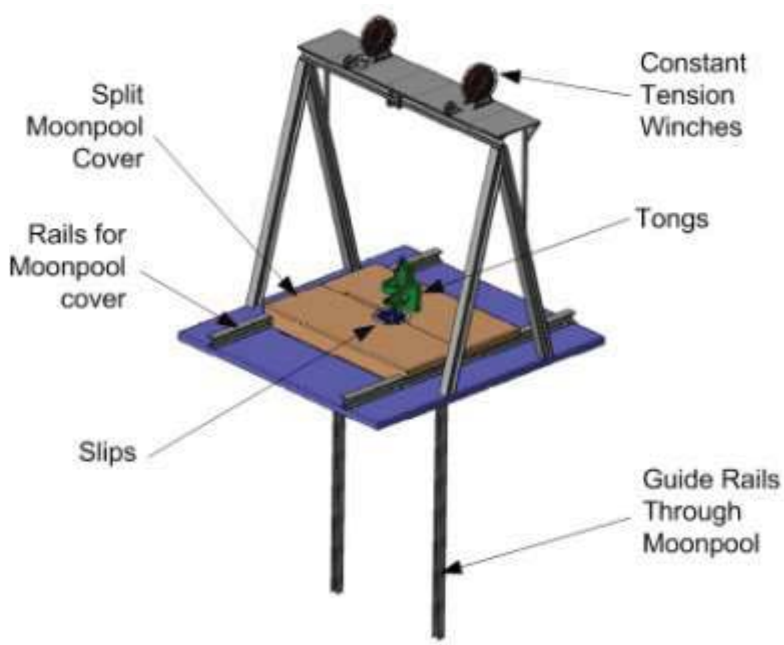

Figure 15
Example of a RADS

The base of the RADS includes provisions to distribute the weight of the module and the static and dynamic loads during riser installation and recovery.

The base has two vertical guide rails that are lowered through attachment assemblies on the base and down through the moonpool to below the keel of the vessel. These guide rails can be installed and removed while at sea. The guide rails are spaced to suit the guide sleeves on the buoyancy modules for SSR installation and recovery.

The base of the RADS supports a split moonpool cover that opens and closes. Suitable guards protect personnel from injury by moving parts. The cover and base have handrails or similar barriers around the opening to prevent falls or injury.

The RADS aligns and stabilizes joints for threading. The RADS has power tongs positioned to close around riser joints and thread or unthread the joints. The RADS handles the riser components without overhead lifts as a safety feature to avoid swinging loads.

8.2 MOTION ISOLATION SYSTEM FOR CT OPERATIONS

A motion isolation system (MIS) is required when a rigid riser extension is brought up to the vessel. All items supported by the MIS are fixed to the earth when the riser extension is connected to the SSR. The MIS maintains nearly constant tension in the riser extension as the vessel heaves and as the equipment load varies. The MIS allows the vessel to change headings to accommodate changes in wind or sea state, without applying torsion to the threaded joints in the riser.

The MIS is an integrated unit that can be fabricated onshore and landed over a moonpool. The base of the MIS is set on the deck of a small vessel and distributes the weight of the MIS module and the suspended load.

Maximum static load on the MIS is anticipated to be the breaking strength of the tubing (approximately 200,000 pounds) plus the weight of the injector. The MIS is designed to prevent equipment damage due to dynamic loads or load changes resulting from sudden release of stuck tubing, or tubing shearing for emergency disconnection.

The MIS engages with the riser extension and isolates it from pitch, roll, and heave motions of the vessel. Stack-up height for the platform and injector are be minimized to reduce relative motion between the vessel and the injector. The MIS may extend down into a moonpool to reduce stack-up height.

The heave isolation portion of the MIS has sufficient power to support the maximum load with maximum vessel heave. The heave cycle for GoM operations is approximately six seconds. The power source for the heave isolation portion can be a combination of passive gas energy storage and active hydraulics.

The MIS maintains tension in the riser extension while the weight on the MIS changes as tubing is run into, or pulled from, the riser.

During operations, forces due to vessel pitch and roll introduce bending moments into the SSR and riser extension. The MIS compensates for these bending moments while avoiding clashing, damaging the MIS or the riser extension, or causing a significant reduction in the fatigue life of either the SSR or the riser extension. The pitch and roll isolation portion does not require hydraulic or electrical energy from the vessel.

9 COIL TUBING EQUIPMENT AND INTERFACES

9.1 CT DESIGN ANALYSIS

The primary differences between CT operations on land and CT operations in deep water are the incremental length of the casing and tubing through the water, the effect of vessel motion on the tubing fatigue life, and the added reservoir isolation features of the SSR system.

Computer modeling and analysis, conducted by NOV CTES, looked at flow rates, pressure, and fatigue life to optimize riser casing diameter, CT diameter, and working depth. Data from this modeling is shown in Appendix B. The overall system is rated for 10,000 psi and is suitable for CT sizes up to 2-7/8 in.

During CT intervention through the SSR, functions to isolate the reservoir are available at the seafloor, at the top of the SSR, and in the CT BOP on the vessel. This arrangement provides three sets of equipment for reservoir isolation as compared to the previous practice of having only one.

Figure 16, provided by Halliburton, includes a drawing of a typical stack-up for CT equipment along with an illustration of Halliburton's 10,000-psi CT equipment (which is available for use in this application).

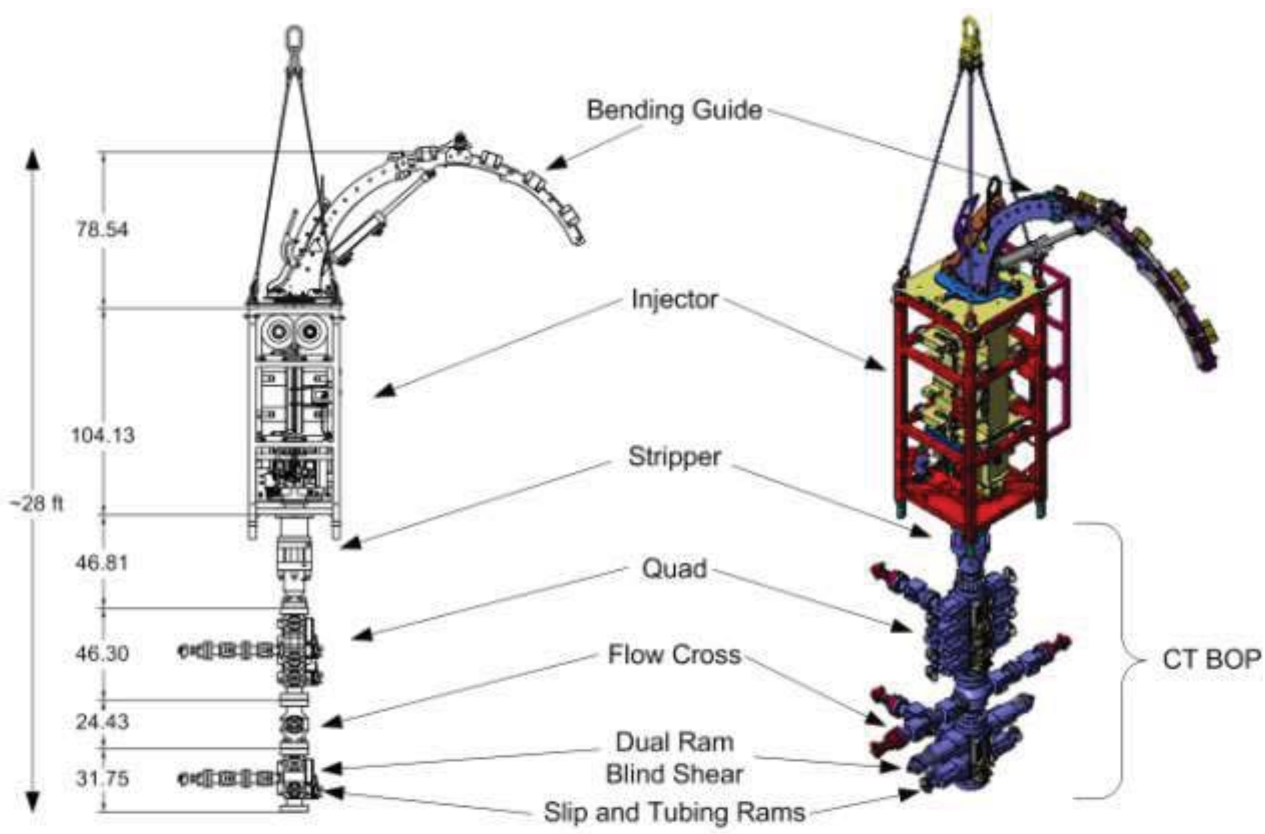

Figure 16
Typical CT Equipment Stack-up, courtesy of Halliburton

9.2 TYPICAL CT COMPONENTS

The system is designed to work with a wide range of existing CT equipment.

Representative baseline CT equipment in this document includes the tubing, injector, packer stripper, surface well control, and accessories such as hydraulic power units and control consoles.

The injector supports the deployed tubing and is a significant load above the MIS. The injector is kept as low as possible to minimize the effect of its weight on the vessel's roll stability.

A bending guide or gooseneck attaches to the top of the injector. This guide is expected to extend 10 ft above the injector and project 6 ft toward the CT reel from the centerline of the injector. Tubing goes from the reel, over the bending guide, and then into the injector.

The CT reel, which stores the tubing, is the heaviest lift for mobilization and is a significant deck load. The weight of the reel depends on the diameter, wall thickness, and length of the tubing. The weight of the deployed tubing will normally not exceed 100,000 pounds but, for work near the total depth limit, the deck load for the reel drive may be near 230,000 pounds when the tubing is filled with fluid. Lighter reels are adequate for most mobilizations. The tubing reel diameter may be 18 feet or more. The base of the reel drive is approximately 15 x 21 feet but may be larger in order to distribute the weight over an adequate area of the deck.

The CT BOP and well control equipment provide the full conventional well control system.

- The stripper provides annular seals at the top of the casing extension.
- The cavities of the Quad, from the top down, include a single function blind ram, a shear ram, connection for an emergency kill line, slip rams, and tubing rams.
- The flow cross below the Quad provides connections for the primary kill line and for the return line.
- A dual ram blind shear is shown below the flow cross. An emergency kill line connection below the blind shear allows pumping into the tubing if it has been sheared by the blind ram.
- Slip rams at the bottom of the stack-up can be engaged to seal around the tubing and to support the tubing if it is sheared or if the injector requires maintenance.

The CT BOP location and equipment arrangement is at the discretion of the CT operator. The slip rams can be mounted in the casing below the SSR buoyancy module. In this location they can support the tubing in the event that it is sheared for emergency disconnection of the vessel from the SSR. Supporting the tubing below the buoyancy eliminates the need for fishing in the riser as part of recovery following an emergency disconnection.

A hydraulic power unit (HPU) and controls package operate both the injector and the CT reel drive.

10 VESSELS

A primary objective of this project is to facilitate increased production of developed reserves by reducing the cost of downhole work in deepwater satellite wells with improved safety for personnel and the environment. Vessel day rate is the largest cost item. Using low-cost vessels as an alternative to the expensive MODUs can reduce the total cost by more than 50% for deepwater well intervention.

The Task 11 report provides more detail on the cost for various vessels that could be used with the SSR system for comparison to MODUs and large well intervention vessels. At the end of 2010, the contracted GoM MODU Semi-Submersibles, which are capable of working in up to 10,000 foot water depth, ranged from $295,000 to $580,000 per day with an average cost of $350,000 per day. These reported day rates were reduced during the economic downturn following the GoM drilling moratorium of 2010 when the average cost of deepwater workover vessels was reduced by about half. These are reported day rates and not spread costs, which typically include the cost of supply boats, helicopter service, and other needs associated with large, complex vessels.

This project includes provisions for using a small construction vessel for SSR installation and a small vessel, rated for hydrocarbons, for downhole intervention. Vessels of opportunity, capable of installing the SSR riser and capable of CT workover operations using the SSR, were in the range of $80,000 per day.

Whether to use a MODU, larger intervention vessel, or single vessel for SSR installation / retrieval and intervention depends on the preference of the operator and service contractor.

As an alternative, this project allows using two low-cost vessels, one for installation / retrieval of the SSR, and the second for deepwater well intervention, optimized for safe handling of returns from the reservoir. Using two vessels improves scheduling flexibility by taking the riser out of the critical path for the downhole work. It also reduces unproductive time for crews and rental equipment, since there is only one set of equipment and one crew onboard, eliminating the need for one crew to wait while the other crew works.

The potential needs for the downhole intervention vessels vary substantially, depending on the nature of the work to be done and the maximum depth of the well. Jobs vary from routine wireline, cleanout to plug and abandonment and up through complex jobs, such as sidetrack drilling with CT. For simple downhole intervention, small readily available vessels of opportunity can be outfitted, while the more complex jobs will require vessels with larger crews and substantial stores of mud, cement, and other consumables. The large number of candidate wells for low-cost intervention is expected to justify conversions and new build vessels.

The RADS and MIS are two systems that have the greatest influence on vessel deck requirements. Conceptual design of these systems is included in Tasks 9 and 10 of this project phase. Detailed designs are planned for subsequent work.

Table 2 contains the basic high-level vessel characteristics. The proposed vessel characteristics are suitable for docks and shore bases along the Louisiana coast.

Table 2 Proposed Characteristics for Vessels	
Installation / Retrieval Vessel	**CT Intervention Vessel**
260 to 300 foot length	260 foot or greater length for stability
RADS – or any combination of tooling adequate for SSR installation and recovery.	MIS – allows the vessel to connect to the stationary SSR.
US flag for regulatory compliance without supply boat.	US flag preferred for efficiency.
DP 2 classification (see Definitions, Section 1.3)	DP 2 classification (see Definitions, Section 1.3)
Deck space adequate for RADS, SSR joints, buoyancy modules, SSD, ROV, and installation tooling, and two cargo box vans	Deck space adequate for MIS, CT equipment including CT BOP, injector and guide frame, quick disconnection segment of the riser extension, ROV, consumables (mud, fluid, etc.), HPU, multiple cargo box vans, and the appropriate intervention equipment that will vary from job to job.
Crane or lowering line suitable for water depth and riser parameters.	Deck crane or lowering line suitable for relocating the wet parked riser extension.
Moonpool at least 15 foot square	Moonpool at least 15 foot square
ROV rated for appropriate depth and work requirements, plus tooling.	ROV rated for appropriate depth and work requirements, plus tooling.
Accommodations, communications, and electrical power for deck equipment.	Accommodations, communications, and electrical power for deck equipment.

Figure 17 and Figure 18 show typical deck arrangements for the installation vessel and intervention vessel.

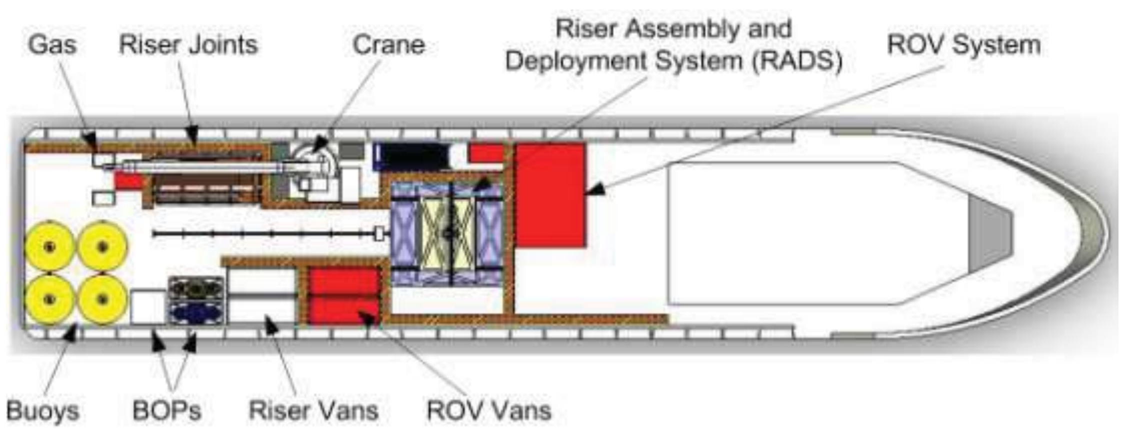

Figure 17
Typical Deck Arrangement for 260 ft Installation Vessel

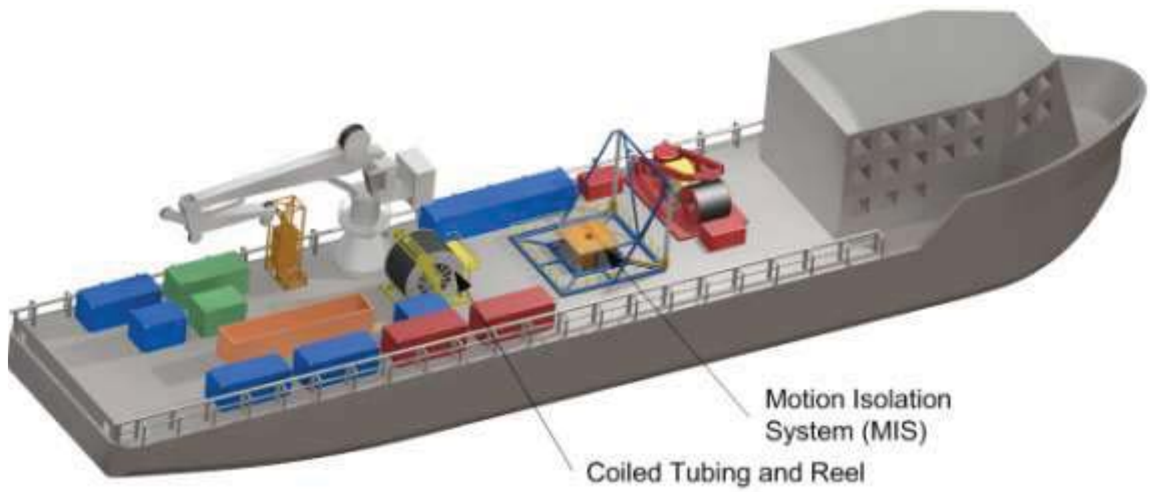

Figure 18
Typical Deck Arrangement for the Intervention Vessel

11 OPERATIONAL PLANNING

As part of Task 7 (refer to Section 1.1), operational procedures, maintenance, and contingency provisions were established for the system. The SSR mobilization and installation procedures incorporate lessons learned from installing the SSR prototype in 2006. Operational planning included reliability analysis and validation of functional capability. After a detailed HAZID review, the procedures were updated to reflect the findings and recommendations from the HAZID.

The procedures are widely applicable and are not significantly influenced by differences in water depth, current profile, type of vessel used, or the nature of the downhole work. One of the major benefits of the system is that vessels can safely disconnect within seconds in an emergency. The vessel can readily disconnect in the event of deteriorating weather conditions, or when necessary to move away from the tree before transferring personnel or equipment. Separate procedures for recovery are not presented because the SSR is recovered by reversing the installation procedure while skipping the steps for pressure testing and load testing.

Operations procedures are at a high level because details will depend on the specific downhole tasks to be done, the vessel selected for the work, and preferences of the client and the CT service contractor.

Detailed information from the operational planning is presented in Appendix D. Below is a high-level overview of the information in Appendix D.

Installation vessel mobilization procedures include:

- Preparatory work for regulatory compliance (permits, certifications, and safety plan), SSR hardware, and staging of equipment and consumables dockside.
- Vessel load-out procedures.
- Offshore procedures:
  - On-site preparatory activities (prior to installation).
  - SSR assembly from 6-5/8 inch drillstring or larger diameter casing.
  - Relocating and testing assembled SSR.
  - Riser casing extension assembly and wet park activity.

Intervention vessel mobilization procedures include:

- Preparatory work for regulatory compliance (permits, certifications, and safety plan), equipment that interfaces to the SSR, CT equipment and consumables, supplies and provisions.
- Vessel load-out procedures.
- Offshore procedures.
  - On-site preparatory activities (prior to downhole work).
  - Connection to the SSR and downhole operations.
- Contingency and optional scenarios:
  - Routine disconnect.
  - Emergency disconnect.
  - Relocation of SSR by intervention vessel.

12 HAZID REVIEW

A hazard identification (HAZID) review of the SSR system was undertaken by a group of more than 20 subject matter experts at the offices of Baker Hughes in Houston. The risk ranking of the identified hazards was done after the HAZID. Mr. F. J. Deegan of Riskbytes Inc., an experienced subsea HAZID facilitator, facilitated the HAZID and produced the report.

The objective of the HAZID process was to identify and mitigate any risks associated with the SSR System. The HAZID team identified hazards / risks for design and operation of the SSR, its interface with the DP vessel, and the proposed CT operations on a live well.

The HAZID review process followed a classical HAZID approach as outlined in the *Loss Prevention in the Process Industries,* by F. P. Lees. The review identified 44 hazards that were later risk ranked. The contractors subsequently identified practical solutions for all 44 items.

12.1 GOALS OF THE HAZID MEETING

The HAZID had the following aims:

- Undertake a structured and comprehensive review of the concept of the SSR system using a formal HAZID process to identify and develop specific hazard scenarios associated with the SSR system.
- Provide a complete, clearly stated list of hazard scenarios, which originate from the systems studied, that have the potential to affect the safety of the facility, including personnel, third party stakeholders, regulators and the environment.
- Assess the risk associated with the individual hazard scenarios.
- Provide a list of actions in terms of specific design, operational, or procedural changes or additional studies to further understand the identified hazards and reduce the associated risk.
- Provide risk management guidance to the SSR project as the project moves forward to the front-end engineering design (FEED) stage.
- Provide assurance that, once all the follow up activities have been verified as satisfactorily completed, all identified hazards in the design and operability of the SSR system have been eliminated or can be managed to a level that is as low as reasonably practicable (ALARP).
- Provide a complete and comprehensive record of the study team's thinking and conclusions drawn during each of the study sessions in a formal HAZID report.

12.2 BOUNDARIES OF THE HAZID

The HAZID focused on vertical trees and did not address construction activities that had little to no risk of injury or hydrocarbon release. The boundary conditions for the HAZID was to identify the *high level* issues associated with the SSR system, including issues around the following *critical activities*:

- Riser disconnects – planned and unplanned.
- Inadvertent disconnect of the riser.
- Riser integrity issues.
- Well control issues when using SSR System.
- Other risk issues.

12.3 OVERALL CONCLUSIONS

The SSR system HAZID brought together 24 industry experts including members of the Nautilus International project team, representatives from operating companies, and associated equipment manufacturers, service contractors, and vessel operator in the structured format of a formal HAZID. Concise documents on system configuration and operational procedures were provided to the attendees for advance reading. The participants had a wide variety of knowledge and experience of subsea system design and operation, including offshore CT operations, and provided a positive contribution to the overall HAZID process. In conclusion of this stage of the HAZID process, subject to the resolution of the recommendations, the following objectives have been achieved:

- A systematic and comprehensive review of critical issues associated with the SSR system design and the associated operations from a DP vessel with CT has been undertaken.
- The HAZID worksheets provide a complete and comprehensive record of the study team's thinking and conclusions drawn by the team.
- This is not the first time that the concept of a SSR had been formally reviewed in a HAZID forum, and it was acknowledged by the team that the process was a useful exercise in the overall design process.
- The majority of the hazard and operability issues identified by the team concerned operability (downtime and associated costs) of using the system.
- The environmental risks identified associated with the SSR system are inherent in any subsea intervention system design.

The HAZID facilitator believes that once the HAZID recommendations have been effectively closed out, it can be concluded that the initial hazards identified will have been effectively managed as part of the concept design process.

As the design stages progress on the SSR system, further HAZID and HAZOP exercises will be scheduled as part of the assurance process. The following is a tentative list of points at which further exercises will be conducted.

1. Load-out and installation of the SSR at the field location using a vessel of opportunity. This should be completed early in the FEED stage, once the vessels particulars and equipment configurations have been developed.
2. Load-out and rig-up of the CT equipment on the specialist vessel. This HAZID should be completed during the early FEED stage once details of the dedicated well service vessel have been defined and equipment configurations have been preliminary laid out.
3. Conduct a formal HAZOP of the proposed CT operations using a proposed well and SSR fluid flow diagrams. This should be undertaken at a point in the FEED design stage when the equipment configurations (layouts, SSD, and CT shear and seal device have been finalized).
4. Conduct a final pre-operational HAZID once the detailed design stage of the project has been completed and a specific well intervention has been identified and dedicated operational procedures have been developed.

Details on the HAZID team members and the HAZID results are in Appendix C.

APPENDIX A: SUPPORTING INFORMATION FROM BOEMRE

The information contained in Section 2.2 in this document is from:

U.S. Dept. of the Interior, Minerals Management Service. *Deepwater Gulf of Mexico 2009: Interim Report of 2008 Highlights*. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Report MMS 2009-016.

The information contained in this appendix is from:

U.S. Dept. of the Interior, Minerals Management Service. *Gulf of Mexico Oil and Gas Production Forecasts: 2009 - 2018*. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Report MMS 2009-012.

This appendix contains:

- Table A1 - Development Systems of Productive Deepwater GOM Projects
- Figure A1 - Figure 2. - Gulf of Mexico Average Annual Oil Production (Past, Present, Projected).
- Figure A1 - Figure 2. - Gulf of Mexico Average Annual Gas Production (Past, Present, Projected).

Table A1: Development Systems of Productive Deepwater GOM Projects

Year of First Production	Project Name[2]	Operator	Block	Water Depth (ft)	System Type
1979	Cognac	Shell	MC 194	1,023	Fixed Platform
1984	Lena	ExxonMobil	MC 280	1,000	Compliant Tower
1988	GC 29[1]	Placid	GC 29	1,540	Semisubmersible/Subsea
1988	GC 31[1]	Placid	GC 31	2,243	Subsea
1989	Bullwinkle	Shell	GC 65	1,353	Fixed Platform
1989	Jolliet	ConocoPhillips	GC 184	1,760	TLP
1991	Amberjack	BP	MC 109	1,100	Fixed Platform
1992	Alabaster	ExxonMobil	MC 485	1,438	Subsea
1993	Diamond[1]	Kerr McGee	MC 445	2,095	Subsea
1993	Zinc	ExxonMobil	MC 354	1,478	Subsea
1994	Auger	Shell	GB 426	2,860	TLP
1994	Tahoe/SE Tahoe	Shell	VK 783	1,500	Subsea
1994	Pompano/ Pompano II	BP	VK 989	1,290	Fixed Platform/ Subsea
1995	Cooper[1]	Newfield	GB 388	2,097	Semisubmersible

Table A1: Development Systems of Productive Deepwater GOM Projects					
Year of First Production	Project Name[2]	Operator	Block	Water Depth (ft)	System Type
1995	Shasta[1]	ChevronTexaco	GC 136	1,048	Subsea
1995	VK 862	Walter	VK 862	1,043	Subsea
1996	Rocky[1]	Shell	GC 110	1,785	Subsea
1996	Popeye	Shell	GC 116	2,000	Subsea
1996	Mars	Shell	MC 807	2,933	TLP/Subsea
1997	Troika	BP	GC 200	2,721	Subsea
1997	Mensa	Shell	MC 731	5,318	Subsea
1997	Neptune	Kerr McGee	VK 826	1,930	Spar/Subsea
1997	Ram-Powell	Shell	VK 956	3,216	TLP
1998	Oyster	Marathon	EW 917	1,195	Subsea
1998	Morpeth	Eni	EW 921	1,700	TLP/Subsea
1998	Arnold	Marathon	EW 963	1,800	Subsea
1998	Baldpate	Amerada Hess	GB 260	1,648	Compliant Tower
1999	EW 1006	Walter	EW 1006	1,884	Subsea
1999	Penn State	Amerada Hess	GB 216	1,450	Subsea
1999	Dulcimer[1]	Mariner	GB 367	1,120	Subsea
1999	Macaroni	Shell	GB 602	3,600	Subsea
1999	Angus	Shell	GC 113	2,045	Subsea
1999	Genesis	ChevronTexaco	GC 205	2,590	Spar
1999	Allegheny	Eni	GC 254	3,294	TLP
1999	Gemini	ChevronTexaco	MC 292	3,393	Subsea
1999	Pluto	Mariner	MC 674	2,828	Subsea
1999	Ursa	Shell	MC 809	3,800	TLP
1999	Virgo	TotalFinaElf	VK 823	1,130	Fixed Platform
2000	Allegheny South	ENI	GC 298	3,307	Subsea
2000	Hoover	ExxonMobil	AC 25	4,825	Spar
2000	Diana	ExxonMobil	EB 945	4,500	Subsea
2000	Black Widow	Mariner	EW 966	1,850	Subsea
2000	Northwestern	Amerada Hess	GB 200	1,736	Subsea
2000	Conger	Amerada Hess	GB 215	1,500	Subsea

Table A1:
Development Systems of Productive Deepwater GOM Projects

Year of First Production	Project Name[2]	Operator	Block	Water Depth (ft)	System Type
2000	King	Shell	MC 764	3,250	Subsea
2000	Europa	Shell	MC 935	3,870	Subsea
2000	Petronius	ChevronTexaco	VK 786	1,753	Compliant Tower
2000	Marlin	BP	VK 915	3,236	TLP
2001	Pilsner	Unocal	EB 205	1,108	Subsea
2001	Marshall	ExxonMobil	EB 949	4,376	Subsea
2001	Prince	El Paso	EW 1003	1,500	TLP
2001	EW 878	Walter	EW 878	1,585	Subsea
2001	Ladybug	ATP	GB 409	1,355	Subsea
2001	Serrano	Shell	GB 516	3,153	Subsea
2001	Oregano	Shell	GB 559	3,400	Subsea
2001	Brutus	Shell	GC 158	3,300	TLP
2001	Typhoon[7]	Helix	GC 237	2,679	TLP
2001	Mica	ExxonMobil	MC 211	4,580	Subsea
2001	MC 68[1]	Walter	MC 68	1,360	Subsea
2001	Crosby	Shell	MC 899	4,400	Subsea
2001	Einset[1]	Shell	VK 872	3,500	Subsea
2001	Nile	BP	VK 914	3,535	Subsea
2002	Madison	ExxonMobil	AC 24	4,856	Subsea
2002	King's Peak	BP	DC 133	6,845	Subsea
2002	Lost Ark	Nobel	EB 421	2,960	Subsea
2002	Nansen	Kerr McGee	EB 602	3,685	Spar
2002	North Boomvang[4]	Kerr McGee	EB 643	3,650	Spar
2002	Navajo	Kerr McGee	EB 690	4,210	Subsea
2002	Tulane	Amerada Hess	GB 158	1,054	Subsea
2002	Manatee	Shell	GC 155	1,939	Subsea
2002	Sangria[1]	Hydro GOM	GC 177	1,487	Subsea
2002	Aspen	BP	GC 243	3,065	Subsea
2002	King Kong	Mariner	GC 472	3,980	Subsea
2002	Yosemite	Mariner	GC 516	4,150	Subsea

Table A1: Development Systems of Productive Deepwater GOM Projects					
Year of First Production	**Project Name[2]**	**Operator**	**Block**	**Water Depth (ft)**	**System Type**
2002	Horn Mountain	BP	MC 127	5,400	Spar
2002	Aconcagua	TotalFinaElf	MC 305	7,100	Subsea
2002	Camden Hills	Marathon	MC 348	7,216	Subsea
2002	Princess	Shell	MC 765	3,642	Subsea
2002	King[9]	BP	MC 84	5,418	Subsea
2002	East Boomvang[4]	Kerr McGee	EB 688	3,795	Subsea
2003	Falcon	Marubeni	EB 579	3,638	Subsea
2003	Tomahawk	Marubeni	EB 623	3,412	Subsea
2003	West Boomvang[4]	Kerr McGee	EB 642	3,678	Subsea
2003	Habanero	Shell	GB 341	2,015	Subsea
2003	Durango[5]	Kerr McGee	GB 667	3,105	Subsea
2003	Gunnison	Kerr McGee	GB 668	3,100	Spar
2003	Dawson[5]	Kerr McGee	GB 669	3,152	Subsea
2003	Boris	BHP Billiton	GC 282	2,378	Subsea
2003	Matterhorn	TotalFinaElf	MC 243	2,850	TLP
2003	Pardner	Anadarko	MC 401	1,139	Subsea
2003	Zia	Devon	MC 496	1,804	Subsea
2003	Herschel/ Na Kika	Shell	MC 520	6,739	Semisubmersible/Subsea[3]
2003	Fourier/ Na Kika	Shell	MC 522	6,940	Semisubmersible/Subsea[3]
2003	North Medusa	Murphy	MC 538	2,223	Subsea
2003	Medusa	Murphy	MC 582	2,223	Spar
2003	East Ansley/Na Kika	Shell	MC 607	6,590	Semisubmersible/Subsea[3]
2004	Devil's Tower	Eni	MC 773	5,610	Spar
2004	South Diana	ExxonMobil	AC 65	4,852	Subsea
2004	Hack Wilson	Kerr-McGee	EB 599	3,650	Subsea
2004	Raptor	Pioneer	EB 668	3,710	Subsea
2004	Harrier[1]	Pioneer	EB 759	4,114	Subsea
2004	Llano	Shell	GB 386	2,340	Subsea
2004	Magnolia	ConocoPhillips	GB 783	4,674	TLP

Table A1: Development Systems of Productive Deepwater GOM Projects					
Year of First Production	**Project Name**[2]	**Operator**	**Block**	**Water Depth (ft)**	**System Type**
2004	Red Hawk	Kerr-McGee	GB 877	5,300	Spar
2004	GB 208	McMoran	GB 208	1,275	Subsea
2004	Glider	Shell	GC 248	3,440	Subsea
2004	Front Runner	Murphy	GC 338	3,330	Spar
2004	Marco Polo	Anadarko	GC 608	4,300	TLP
2004	Holstein	BP	GC 645	4,340	Spar
2004	Kepler/Na Kika	BP	MC 383	5,759	Semisubmersible/Subsea[3]
2004	Ariel/Na Kika	BP	MC 429	6,240	Semisubmersible/Subsea[3]
2004	Coulomb/ Na Kika	Shell	MC 657	7,591	Semisubmersible/Subsea[3]
2004	Ochre	Mariner	MC 66	1,144	Subsea
2004	MC 837	Walter	MC 837	1,524	Subsea
2005	GC 137	Nexen	GC 137	1,168	Subsea
2005	Citrine	LLOG	GC 157	2,614	Subsea
2005	Baccarat	W and T Offshore	GC 178	1,404	Subsea
2005	K2	Anadarko	GC 562	4,006	Subsea
2005	Mad Dog	BP	GC 782	4,420	Spar
2005	Triton/Goldfinger	Eni	MC 728	5,610	Subsea
2005	Killer Bee	Walter	MC 582		Subsea
2005	Swordfish	Noble	VK 962	4,677	Subsea
2006	SW Horseshoe	Walter	EB 430	2,285	Subsea
2006	Dawson Deep	Kerr McGee	GB 625	2,965	Subsea
2006	Lorien	Noble	GC 199	2,315	Subsea
2006	K2 North	Anadarko	GC 518	4,049	Subsea
2006	Constitution	Kerr McGee	GC 680	4,970	Spar
2006	Ticonderoga	Kerr McGee	GC 768	5,272	Subsea
2006	Rigel	Eni	MC 252	5,225	Subsea
2006	Gomez	ATP	MC 711	2,975	Semisubmersible
2006	Seventeen Hands	Eni	MC299	5,881	Subsea
2007	Vortex/Ind. Hub	Anadarko	AT 261	8,344	FPS/Subsea[6]

Table A1:
Development Systems of Productive Deepwater GOM Projects

Year of First Production	Project Name[2]	Operator	Block	Water Depth (ft)	System Type
2007	Jubilee/Ind. Hub	Anadarko	AT 349	8,825	FPS/Subsea[6]
2007	Merganser/Ind. Hub	Anadarko	AT 37	8,015	FPS/Subsea[6]
2007	San Jacinto/Ind. Hub	Eni	DC 618	7,850	FPS/Subsea[6]
2007	Spiderman/Ind. Hub	Anadarko	DC 621	8,087	FPS/Subsea[6]
2007	Cottonwood	Petrobras	GB 244	2,130	Subsea
2007	Shenzi[8]	BHP Billiton	GC 652	4,300	Subsea
2007	Atlantis	BP	GC 787	7,050	Semisubmersible
2007	Mondo NW/Ind. Hub	Anadarko	LL 1	8,340	FPS/Subsea[6]
2007	Cheyenne/Ind. Hub	Anadarko	LL 399	8,951	FPS/Subsea[6]
2007	Atlas-Atlas NW/Ind. Hub	Anadarko	LL 50	8,934	FPS/Subsea[6]
2007	Wrigley	Newfield	MC 506	3,911	Subsea
2007	Deimos	Shell	MC 806	3,106	Subsea
2007	Q/Ind. Hub	Hydro	MC 961	7,925	FPS/Subsea[6]
2007	Anduin	ATP	MC 755	2,904	Subsea
2007	Tiger	Deep Gulf Energy	GC 195	1,900	Subsea
2008	Neptune	BHP Billiton	AT 575	4,232	TLP
2008	MC 161	Walter	MC 161	2,924	Subsea
2008	Raton	Nobel	MC 248	3,290	Subsea
2008	Blind Faith	ChevronTexaco	MC 696	6,989	Semisubmersible
2008	Valley Forge	LLOG	MC 707	1,538	Subsea
2008	Thunder Horse	BP	MC 778	6,037	Semisubmersible
2008	Bass Lite	Mariner	AT 426	6,634	Subsea
2009	Pegasus	Eni	GC 385	3,498	Subsea
2009	Mirage and Morgus	ATP	MC 941	4,000	Mini TLP
2009	Dorado	BP	VK 915	3,236	Subsea
2009	GB 302	Walter	GB 302	2,410	Subsea
2009	Tahiti	ChevronTexaco	GC 640	4,000	Spar
2009	Longhorn	Eni	MC 502	2,442	Subsea
2009	Isabela	BP	MC 562	6,500	Subsea
2009	Thunder Hawk	Murphy	MC 734	6,050	Semisubmersible

Table A1: Development Systems of Productive Deepwater GOM Projects					
Year of First Production	Project Name[2]	Operator	Block	Water Depth (ft)	System Type
2009	Clipper	ATP	GC 299	3,452	
2009	MC 72	LLOG	MC 72	2,013	
2009	MC 583	Walter	MC 583	2,487	
2009	Geauxpher	Mariner	GB 462	2,823	
2009	Thunder Horse North	BP	MC 776	5,660	
2009	Unreleasable[10]				
2009	Unreleasable[10]				
2009	Unreleasable[10]				
2010	Telemark	ATP	AT 63	4,385	Mini TLP
2010	Great White	Shell	AC 857	8,000	Spar
2010	MC 241	Walter	MC 241	2,415	
2010	Caesar Tonga	Anadarko	GC 683	4,672	Subsea
2010	Silvertip	Shell	AC 815	9,226	Subsea
2010	Tobago	Shell	AC 859	9,627	Subsea
2010	Cascade	Petrobras	WR 206	8,143	FPSO/Subsea
2010	Chinook	Petrobras	WR 469	8,831	FPSO/Subsea
2010	Droshky	Marathon	GC 244	2,900	
2010	Unreleasable[10]				
2010	Unreleasable[10]				
2011	Ozona	Marathon	GB 515	3,000	
2012	Unreleasable[10]				
2012	Unreleasable[10]				
2013	Unreleasable[10]				
2013	Unreleasable[10]				
2013	Unreleasable[10]				
2013	Unreleasable[10]				
2013	Unreleasable[10]				
2013	Unreleasable[10]				
2013	Unreleasable[10]				
2013	Unreleasable[10]				

Table A1:
Development Systems of Productive Deepwater GOM Projects

Year of First Production	Project Name[2]	Operator	Block	Water Depth (ft)	System Type
2013	Puma	BP	GC 823	4,129	
2014	Unreleasable[10]				
2016	Unreleasable[10]				

1 Indicates projects that are no longer on production.
2 The previous edition of this report listed deepwater fields, whereas this version lists deepwater projects.
3 Na Kika FPS is located in Mississippi Canyon Block 474 in 6,340 ft (1,932 m) of water.
4 2004 Report referred to entire area as Boomvang
5 Included in 2004 Report with Gunnison
6 Independence Hub FPS will be located in Mississippi Canyon Block 920 in 7,920 ft (2,414 m) of water.
7Formerly known as Typhoon under ChevronTexaco operation, now named Phoenix under Helix operation
8 Formerly known as Genghis Khan
9 Includes King South
10 Unreleasable – operator has commitment to produce and/or is planning to develop project but has not publicly released project information.
AC = Alaminos Canyon
AT = Atwater Valley
DC = De Soto Canyon
EB = East Breaks
EW = Ewing Bank
GB = Garden Banks
GC = Green Canyon
LL = Lloyd Ridge
MC = Mississippi Canyon
VK = Viosca Knoll
WR = Walker Ridge

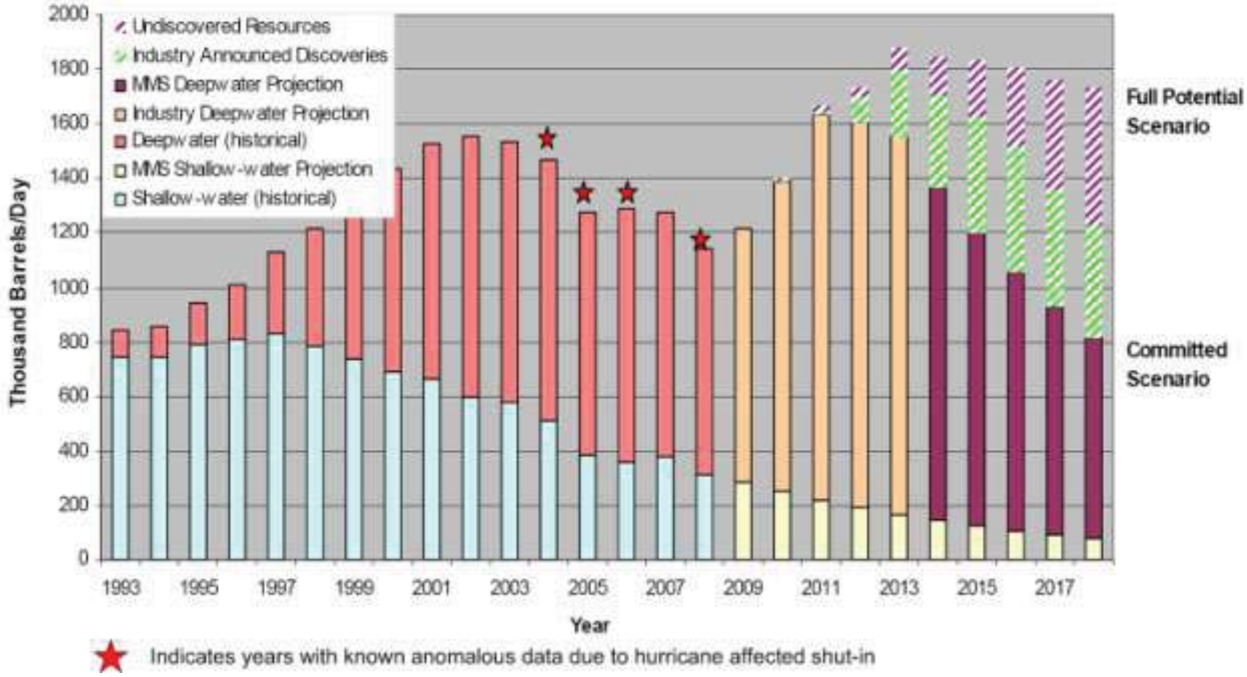

Figure A1:
GoM Average Annual Oil Production (Past, Present, Projected)

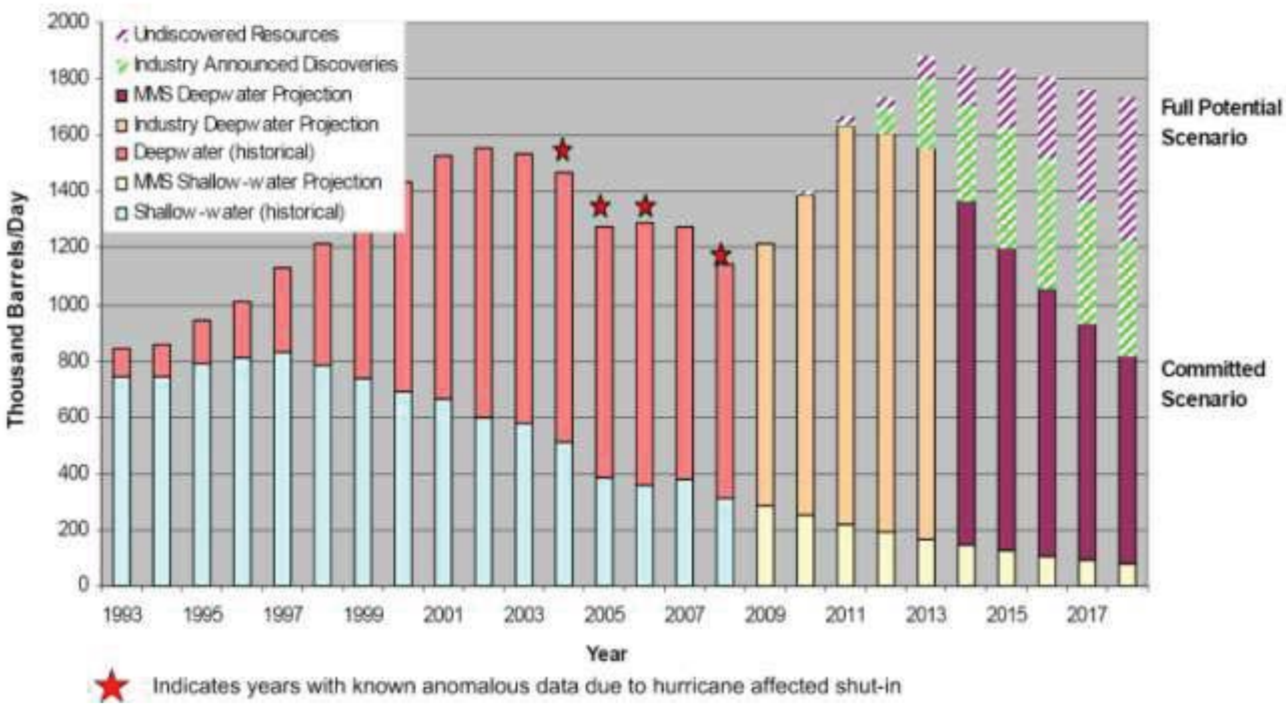

Figure A2:
GoM Average Annual Gas Production (Past, Present, Projected)

APPENDIX B: CT EQUIPMENT MODELING BY NOV CTES

CALCULATIONS AND CONCLUSIONS ON HOW TOTAL DEPTH IS LIMITED BY AVAILABLE TUBING STRENGTH

The calculations show that straight wall tubing strings can reach total depth greater than 33,000 feet using available 120,000-psi material, and tapered tubing strings can reach 40,000 feet for reasonable buoyancy and pressure. The optimum tubing diameter for tradeoff of pump pressure and fatigue life is from 2-3/8 inch to 2-7/8 inch. Fatigue life goes down as tubing diameter increases, and flow loss goes up as tubing diameter decreases. These factors determine the choice of tubing, which in turn defines the maximum weight of tubing and therefore the maximum anticipated deck load for the CT reel. The maximum load on the motin isolation system (MIS) is the weight of the injector, plus the breaking strength of the tubing.

From the viewpoint of downhole operations, the incremental length of casing and tubing through the water column and the effect of vessel motion are the primary differences between onshore operations and working in deepwater with the SSR.

HYDRAULIC FLOW IN THE CT AND TUBING AND CASING

Computer runs by NOV CTES included models of hydraulic flows in the CT and production tubing / SSR casing return flow path for a reservoir 12,000 feet below the seafloor with water depth of 3,000 feet. Fluid properties were per Applied Drilling Engineering textbook published by SPE (page 71) with fluid weights of 10, 12, 14, and 16 lb/gal. Relatively high but commonly used grades of tubing were considered. Tubing length of 20,000 feet and outside diameters from 1-1/2 inch to 3-1/2 inch were considered, using standard sizes of coil OD and ID in this range, with emphasis on the 2-3/8 inch diameter and SSR casing diameters of 5-1/2 inch and 6-5/8 inch.

NOV CTES modeled 5 inch well casing liner / tubing diameter with a 5 inch riser; 7 inch well casing liner / tubing diameter; and a 7 inch riser for wells with tubing; and a completion with no tubing using a tapered casing string to total depth with the final casing size of 7 in. as follows:

- Open-ended (no motor or bit) with initial flow rate of 20 gpm, increasing in increments of 20 gpm up to 160 gpm, or to the upper limit that can be reached for the tubing diameter under consideration.
- Mud motor and bit case with pressure drops for typical PDC / Diamond bits and both turbine motor and positive displacement motor for milling and drilling out of the specific casing size. The drilling case assumes a 500 foot lateral and a 1,000 foot lateral and a 4-1/2 inch bit for drilling out of 7 inch casing.

Analysis results are summarized in Figure B1 through B8. Figure B6 shows that the number of trips for CT tubing is limited. One trip is defined as bending the tubing off the reel and into the vertical riser, and then reversing the motion for recovery to the reel. Vessel motion would fatigue the tubing rapidly if the tubing were run off of and back onto the reel each time the vessel heaves. The baseline system includes provisions to protect the tubing from fatigue while holding the deployed tubing stationary in the well. Preliminary analysis indicated that, up to some threshold of vessel motion, this flexure is primarily in the elastic range and does not materially reduce the fatigue life of the tubing. Additional analysis during Task 9 determined the threshold motion for adequate fatigue life under expected operating conditions from a small vessel for alternate equipment arrangements. An optimum arrangement has been determined and will be used.

NOV CTES

Maximum Well Depth

Vertical Well w/Straight-Wall CT (constant thickness)

- Max Allowable Stress = 80% of Yield Stress
- Max Allowable Force = Force in CT @ Max Allowable Stress
- Incl. Margin of Overpull (MOP) = 10% of Max Allowable Force
- Same Fluid Inside & Outside the CT

Fluid Density	Grade of CT = Yield Stress (*Kpsi*)						
PPG	70	80	90	100	110	120	130
0	14,841	16,961	19,081	21,201	23,322	25,442	27,562
2	15,309	17,496	19,683	21,871	24,058	26,245	28,432
4	15,808	18,067	20,325	22,583	24,842	27,100	29,358
6	16,341	18,675	21,010	23,344	25,678	28,013	30,347
8	16,910	19,326	21,742	24,158	26,573	28,989	31,405
10	17,521	20,024	22,527	25,030	27,533	30,036	32,539
12	18,178	20,775	23,371	25,968	28,565	31,162	33,759
14	18,885	21,583	24,281	26,979	29,677	32,375	35,073
16	19,650	22,458	25,265	28,072	30,879	33,686	36,494

Maximum CT Depth (ft)

RPSEA Project #1502-01

Figure B1
Maximum Well Depth

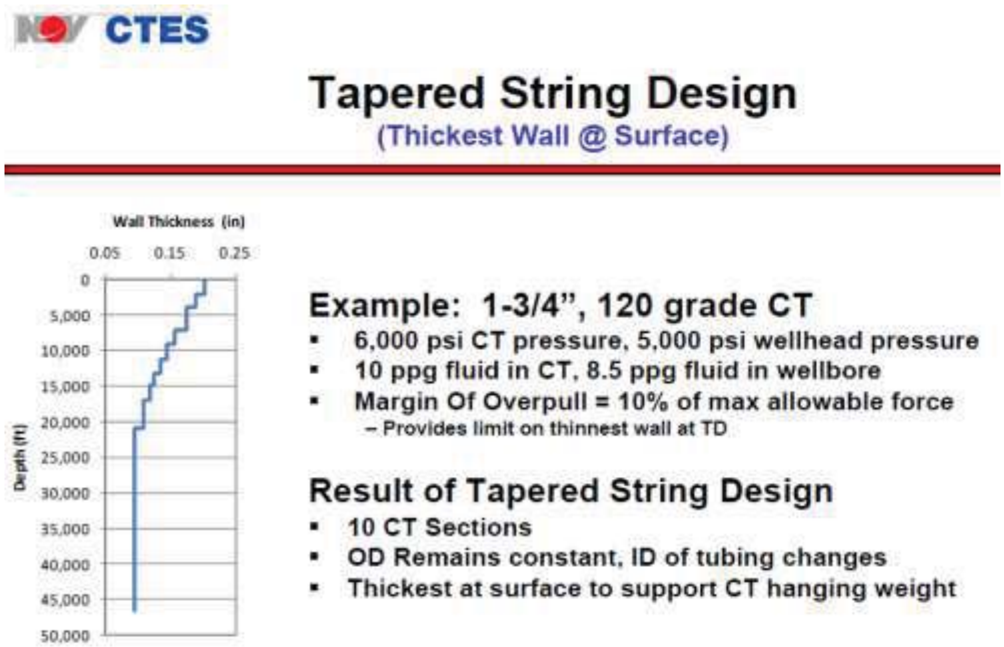

Figure B2
Tapered String Design

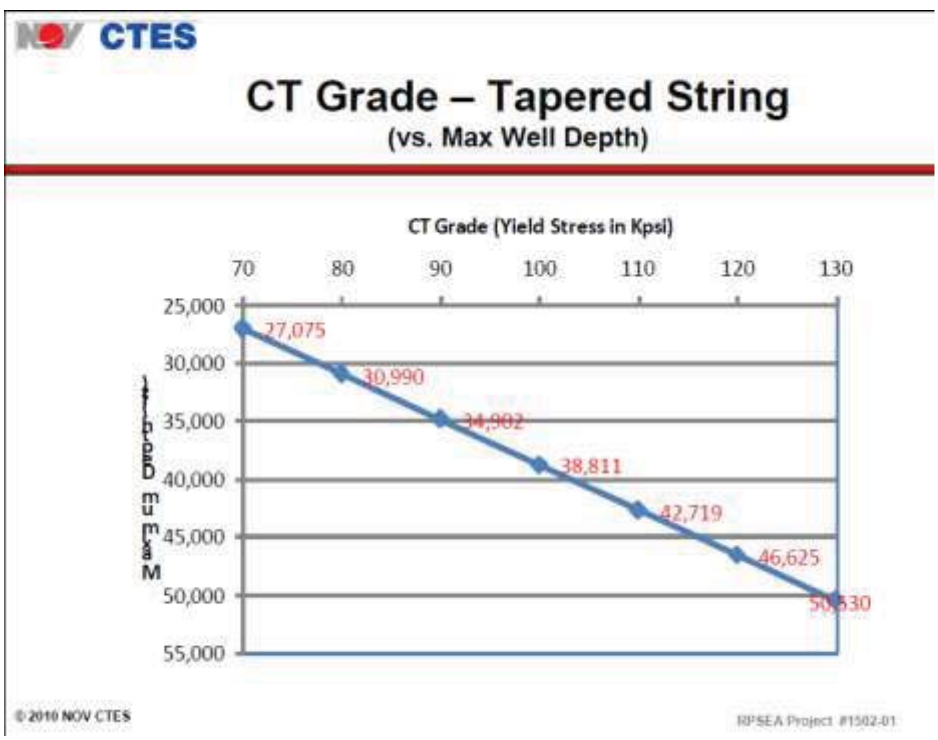

Figure B3
CT Grade – Tapered String

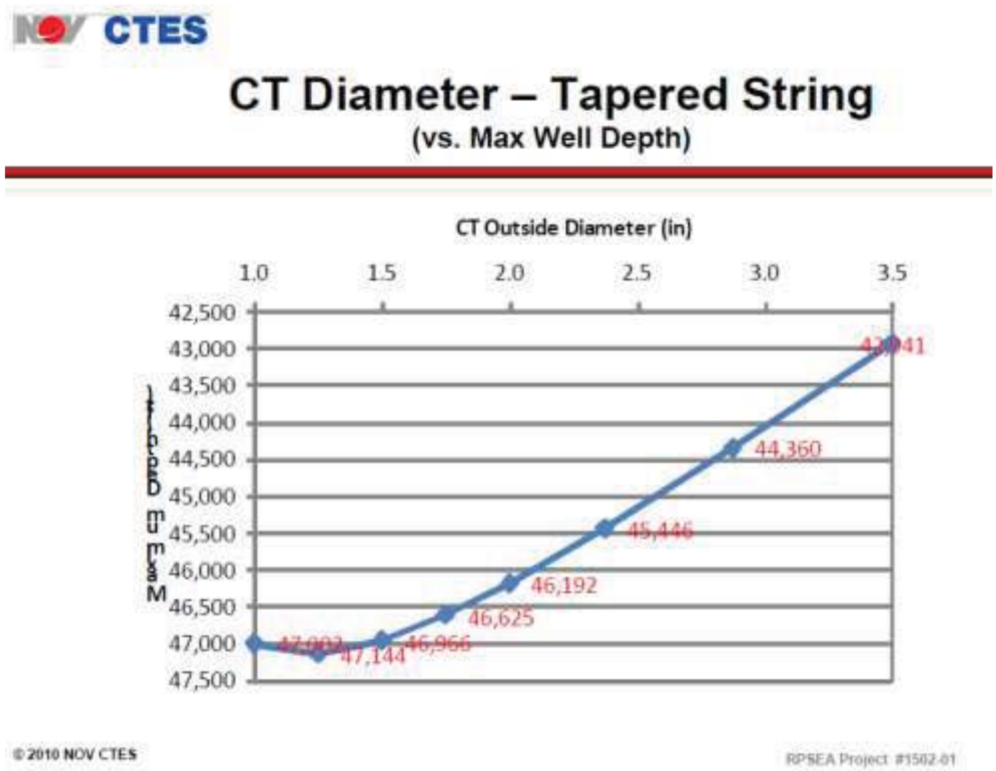

Figure B4
CT Diameter – Tapered String

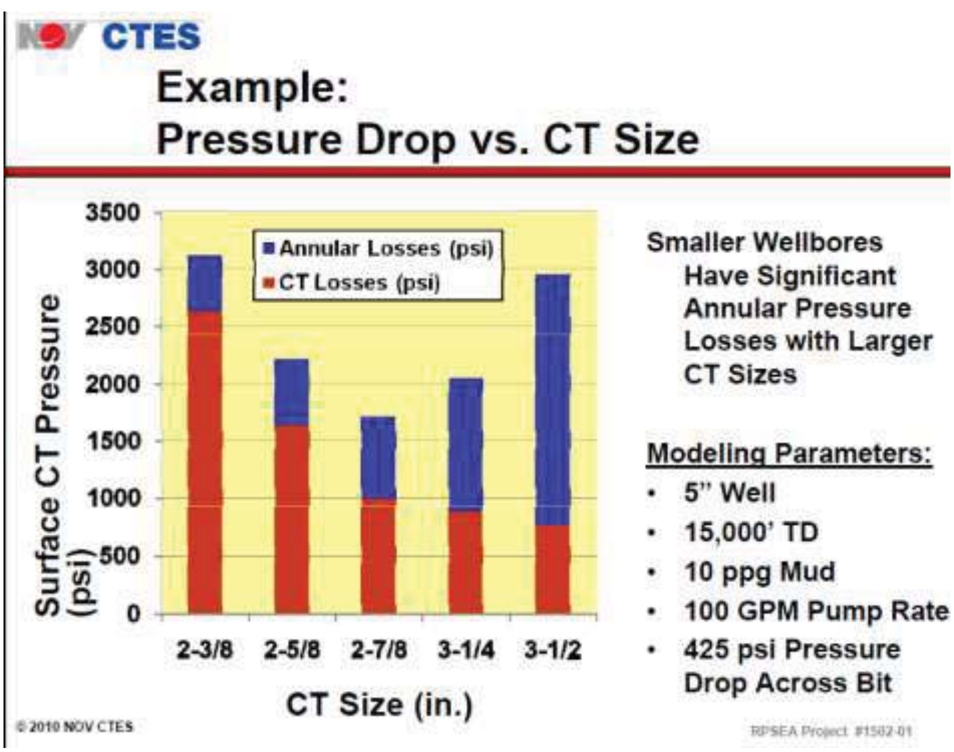

Figure B5
Example: Pressure Drop vs. CT Size

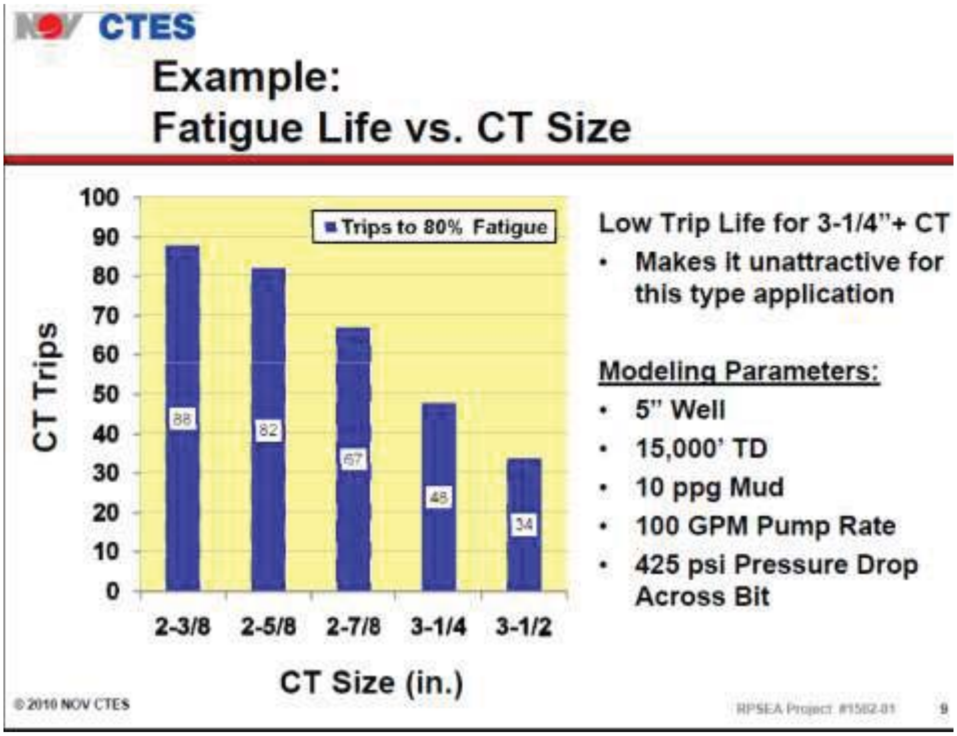

Figure B6
Example: Fatigue Life vs. CT Size

NOV CTES

Tapered CT String Designs

(TrueTaper Sections Not Included)

CT Outside Diameter (in)	1 1/2	1 3/4	2	2 3/8
Margin of overpull (lb)	11,250	14,650	19,800	30,500
Wet weight of CT string (lb)	90,198	116,812	148,681	197,585
Dry Weight of CT string (lb)	68,270	85,871	107,468	136,960
Volume of fluid in CT string (bbl)	53.7	76.4	102.6	152.6
Maximum pickup Weight	74,390	94,713	120,449	160,221
CT Yield Force at Surface	92,987	118,391	150,561	200,277
Wall Thickness of Section (in)	**Section Length (ft)**			
0.250				2,726
0.225			2,653	2,685
0.203		1,992	2,016	2,036
0.188	1,849	1,877	1,896	1,912
0.175	2,946	2,982	3,007	3,031
0.156	1,924	1,943	1,958	3,988
0.145	2,084	2,103	2,119	
0.134	1,855	1,870	21,352	18,627
0.125	1,552	22,230		
0.118	22,796			

Figure B7
Tapered CT String Design

NOV CTES

Example:
Reel Size & Weight vs. CT Size

CT Outside Diameter (in)	1 1/2	1 3/4	2	2 3/8
Core diameter (in)	72.0	84.0	96.0	114.0
Width between flanges	96	96	126	126
Number of turns per wrap	64.0	54.9	63.0	53.1
Number of wraps	21	21	17	17
Length of CT possible	36,417	36,417	36,450	36,450
Flange Diameter (in)	138	161	168	200
Estimated weight of empty reel (lb)	22,000	25,000	30,000	32,000
Estimated reel width (ft)	11.5	11.5	14.0	14.0
Estimated reel length (ft)	16.0	17.5	18.0	20.5
Estimated reel height (ft)	13.0	14.5	15.0	17.5
Total weight with dry CT (lb)	90,270	110,871	137,468	168,960
Total weight with wet CT (lb)	112,198	141,812	178,681	229,585

Figure B8
Example: Reel Size and Weight vs. CT Size

APPENDIX C: HAZID STUDY TEAM MEMBERS AND RESULTS

Representatives from the RPSEA 08121-1502 project team, downhole intervention contractors, equipment manufacturers, drillers, vessel operators, and representatives from several sponsoring operators assembled to participate in the HAZID review (Table D1).

Table D2 lists the HAZID guide words and explanations, and Table D3 lists the HAZID recommendations.

Table D1:
List of HAZID Review Attendees
(✶ = Full Time; P/T = Part Time)

Name	Company	Role/Specialization	Experience (Yr)	Pre-Meeting	Day 1
Thomas Williams	Nautilus Intl.	Project Administrator	41	✶	✶
JG Nutter	XTREME Coil				✶
David Traugott	NOV CTES			✶	✶
Robert van Kuilenburg	Huisman U.S.			✶	✶
John H. Cohen	AGR Subsea Inc.	R&D Technology Manager	37		✶
Dana Witt	Chevron	Sr. Drilling Advisor			✶
Shafiq Khandoker	Hess Corp				P/t
Chuck Yemington	Nautilus Intl.	Managing Director Nautilus Intl.	33	✶	✶
Perry Courville	Halliburton	Group Manager CT and Hydraulic Workover	31		✶
Colin Morris	Shell				P/t
Dr.Keith Millheim	Nautilus Intl.	Designer / Engineer of Self Supporting Riser	40	✶	✶
David Manning	Tidewater	Manager of Engineering	22	✶	✶
Jim Yu	INTECSEA	Manager Tendons and Risers	23	✶	✶
Tony Moore	GE OIL & GAS			✶	✶
Martin Davidson	GMC	System Specifications	28	✶	✶
Iain Duncan	GMC	System Specifications	31	✶	✶
Eugene Ratterman	Baker Hughes	Well Completion Pumping and Intervention	20		✶
Vance Nixon	GE Oil & Gas	Project Manager	20	✶	✶
Cort Peavy	Baker Hughes	Product Line Manager Subsea Intervention	12		✶
Ray Staiwicz	Chevron	Global Intervention Manager			✶
Teresa Harlow	Nautilus Intl.	HAZID Scribe		✶	✶
T J Maa	GE OIL & GAS			✶	
Ryan Stigberg	INTECSEA			✶	

Table D1: List of HAZID Review Attendees (✶ = Full Time; P/T = Part Time)					
Name	**Company**	**Role/Specialization**	**Experience (Yr)**	**Pre-Meeting**	**Day 1**
Jonathan Deegan	Riskbytes Inc.	HAZID Facilitator	25	✶	✶

Table D2: HAZID Guide Words	
Guideword (Key Word)	**Explanation**
Met-ocean Issues	
Loop Current	Loop currents affects the riser when deployed
Vortex Induced Vibration	VIV affects the riser when deployed
Seabed currents	High seabed currents affect the riser
Hurricane abandonment	Hurricane is approaching the area of operations
Riser Failure Modes	
External Corrosion	External corrosion of the riser
Internal Corrosion	Internal corrosion on the riser
Loss of Surface Tension	Failure of Surface Tensioner System
Loss of Riser Buoyancy	Failure of the Riser Buoyancy System
Damage to riser internals	Gouging of the riser or wear due to contact on internal surface
Loss of Containment	Failure of the Riser e.g. connector failure crack propagation
Fatigue of the riser	Fatigue of the riser due to prolonged exposure
Control System or Service Supply Issues	
Inadvertent Disconnect	The Riser inadvertently disconnects from the subsea tree
Unable to isolate	Control System failure results in failure to isolate the well
Loss of Services to Equipment	Loss of air or electrical power to equipment from vessel
Loss of Communications	Loss of communications with Subsea Equipment
Communications Failure	Failure of Communications on Vessel
Handling Issues	
Deck Space	Restrictive deck space on vessel
Deck Loading	Limited deck loading capacity
Lifting equipment	Crane capacities, crane operating arcs,
Dropped Objects	Dropped Object to deck or to subsea
Pressure stored Energy	Working around pressure and stored energy
Vessel motions	Working on deck with motions of 300 ft vessel
Vessel Hazards	

Table D2: HAZID Guide Words	
Guideword (Key Word)	**Explanation**
Loss of DP	Loss of DP Position - Drive Off - Drift Off - Force Off
Fire on Vessel	Fire or other emergency on vessel
Loss of Vessel Stability	Loss of the vessel stability while on operations
Other Hazards	
Errant Vessel	Errant vessel in close proximity to SSR operation
SIMOPs	Simultaneous Operations (Production, Construction etc).
Environmental Issues	
Handling Hydrocarbons	Hydrocarbons at surface or hydrocarbon contaminated fluid
Spills	Spill of chemicals or well fluids
Regulatory Issues	
Changes in Legislation	Changes in regulations in GoM
Technology and Project Issues	
New or Un-proven Technology	Project using new or unproven technology or technology step outs
Design Uncertainty	Project has design uncertainties pressures, temperatures fluid types, etc.

The HAZID of the SSR system generated a total of 44 recommendations. These recommendations are outlined Table D3. The format of the tables is as follows:

- First column is the recommendation number.
- Second column contains the cause of the recommendations
- The third column is the recommendation categorization either Operability or HSE,
- The fourth column is the responsible discipline engineer for addressing the recommendation.

Table D3: HAZID Results			
No.	**Cause of Hazard**	**Recommendation**	**Actionee**
SSR Disconnect and Reconnect			
1	Shear seal - riser disconnect.	SSD consists of shear ram on top blind ram on bottom review configuration of SSD for isolation on shearing of equipment across it.	GE Oil & Gas
2	Shear seal - riser disconnect.	Make the shear ram capable of cutting all tools that could be across it.	GE Oil & Gas
3	Shear seal - riser disconnect.	Procedures to ensure that on planned disconnect procedures will allow the riser to be sealed.	Nautilus Intl.
4	Coil Tubing is sheared.	Review system for worst case weight loss due to shearing of coil and load path reacts.	Nautilus Intl.
5	Coil Tubing is sheared.	As part of design, ensure that anti recoil valves are activated prior to shearing.	Nautilus Intl.
6	Vessel loss of station keeping.	Review requirement for extra protection that DP3 would provide and assess whether the additional costs provide a risk benefit.	Nautilus Intl.
7	Coil sheared at upper shear point only (alternate shear point).	Assess whether SSD will require an acoustic activation system.	Nautilus Intl.
8	Coil sheared at upper shear point only (alternate shear point).	Review system configuration to enable fishing of sheared coil under various sizes.	Nautilus Intl.
9	Failure to shear at subsea SSD.	Assess configuration of upper shear point for adequate level of redundancy and reliability.	GE Oil & Gas
10	Failure to shear at subsea SSD.	Evaluate SSD and tree valve closure sequence and timing and shearing.	GE Oil & Gas
11	Unknown well conditions below shear point [upper shear seal point].	Review specification of upper shear point to allow for monitoring of pressures and ability to circulate.	Nautilus Intl.
12	Unknown well conditions below shear point [upper shear seal point].	Develop SSR CT intervention well control procedures.	Nautilus Intl.
13	Unknown well conditions below shear point (SSD).	Prior to opening of SSD appropriate procedures should be followed to assess well bore conditions below SSD.	Nautilus Intl.
14	Unknown well conditions below shear point (SSD).	Further develop circulating hose and monitoring device specification as project progresses.	Nautilus Intl.
15	Failure to shear at upper shear point.	Investigate possibility of installing surface shear device for coil.	Nautilus Intl.
16	Failure to shear at upper shear point.	Evaluate feasibility of installing a retention valve which has a cutting capability.	Nautilus Intl.

Table D3: HAZID Results			
No.	**Cause of Hazard**	**Recommendation**	**Actionee**
17	Incorrect closure sequence at sea floor.	Assess the risks associated with tree valve lockout system.	Nautilus Intl.
18	Incorrect closure sequence at sea floor.	Assess reliability requirement for dual HP and LP supplies to subsea tree with automatic switchover upon failure one supply	GMC
19	Failure to disconnect at the upper disconnect point.	Review redundancy for upper riser connector functioning.	Nautilus Intl.
20	Failure to disconnect at the upper disconnect point.	Determine riser connection weak point for failure.	Nautilus Intl.
21	Failure to disconnect at the upper disconnect point.	Investigate dropping riser extension system should upper riser connector fail to disconnect.	Nautilus Intl.
22	Failure to disconnect at the upper disconnect point.	Investigate design weak link in riser extension.	Nautilus Intl.
23	Failure to disconnect at the upper disconnect point.	Redundant connectors at riser extension connection point.	Nautilus Intl.
24	Riser disconnect angle to great for clean disconnect.	Investigate the use of a high angle connector at riser extension connector point.	Nautilus Intl.
25	Hydrocarbons in the riser above the subsea device SSD.	Recommend that the upper shear point has facility for monitoring pressures below the rams.	Nautilus Intl.
26	Retainer valve in riser extension system fails to operate with hydrocarbons in the system.	Evaluate redundancy in retainer valve system operations.	Nautilus Intl.
27	Retainer valve in riser extension system fails to operate with hydrocarbons in the system.	Evaluate feasibility of installing a retainer valve which has a cutting capability.	Nautilus Intl.
28	Damage to the riser Self Supporting mandrel.	Review design of upper riser connector to minimize potential damage during disconnect and reconnect and assess risks of possible options.	Nautilus Intl.
29	Trapped pressure in riser has dissipated during time vessel off location.	If failure in upper shear device, investigate ability to recover upper shear device using ROV and wire system.	Nautilus Intl.
Inadvertent Disconnect			

Table D3: HAZID Results			
No.	**Cause of Hazard**	**Recommendation**	**Actionee**
30	Inadvertent disconnect of upper riser connector with common umbilical providing power and signal to retainer valve, connector, upper shear seal system, SSD and subsea tree.	Do not configure the riser system umbilical into a common system where single point failure could result in possible well control.	GMC
31	Inadvertent disconnect of upper riser connector with two umbilicals one providing power and signal to retainer valve, connector, upper shear seal system, and independent umbilical providing power and signal to SSD and subsea tree.	Review design function of upper shear system to insure well integrity upon disconnect of riser extension connector.	Nautilus Intl.
32	Inadvertent disconnect of upper riser connector with two umbilicals one providing power and signal to retainer valve, connector, upper shear seal system, and independent umbilical providing power and signal to SSD and subsea tree.	Protocols need to be developed for loss of station keeping and inadvertent disconnect of riser.	Nautilus Intl.
33	Inadvertent disconnect of upper riser connector with two umbilicals one providing power and signal to retainer valve, connector, upper shear seal system, and independent umbilical providing power and signal to SSD and subsea tree.	Ensure functions which could result in an advertent disconnect are secured.	Nautilus Intl.
34	Inadvertent operation of lower SSD connector.	SSD to tree connector to be configured for ROV actuation only.	GE Oil & Gas
35	Inadvertent operation of lower SSD connector.	Ensure that detail reviews are undertaken for tree to SSD connector system for potential failure resulting in disconnect.	Nautilus Intl.
36	Inadvertent operation of lower SSD connector.	Examine possible methods for riser retention should inadvertent disconnect occur.	Nautilus Intl.
37	Inadvertent operation of lower SSD connector.	Examine potential for interlock from tree to SSD to prevent inadvertent disconnect.	Nautilus Intl.
Riser Integrity			
38	Corrosion	Assess requirements for corrosion protection on riser.	Nautilus Intl.
39	Corrosion	Develop corrosion compatibility system for riser.	Nautilus Intl.

Table D3: HAZID Results			
No.	**Cause of Hazard**	**Recommendation**	**Actionee**
40	Fatigue	Evaluate system for mitigating fatigue issues, i.e., strakes, fairings, buoyancy elevation and drill string tracking system.	INTECSEA Nautilus Intl.
41	Washing out	Analyze makeup equipment to prevent damage to connections [dedicated pipe handling equipment on installation vessel].	Nautilus Intl.
42	Gouging	Investigate whether internals of riser need to be coated to prevent damage due to erosion caused by sand, corrosion, etc.	Nautilus Intl.
43	Hydrate formation in riser.	Develop protocol for hydrate remediation.	Nautilus Intl.
Equipment Layout on Vessel			
44	Handling pipe on vessel.	Ensure that appropriate pipe handling equipment is used to handle pipe on the installation vessel.	Nautilus Intl.

APPENDIX D: OPERATIONAL PROCEDURES

SSR MOBILIZATION PROCEDURES

This section focuses on work to be done before sail away for an offshore demonstration. Vessel specific procedures can be prepared only after the vessel is contracted so procedures in this document are necessarily at the overview level. Work following contracting begins on two paths, one for installation and recovery of the riser and the other for downhole operations.

SSR Preparatory Work

Planning for mobilization, preparation of the SSR hardware, and staging at dockside are addressed here. Categories of preparatory work are primarily:

- Permits, procedures, certifications, safety plan, QC plan for installation, and engineering documentation
- Preparation of SSR components
- Equipment spares and consumables for SSR installation
- Vessel with supplies, provisions, and consumables
- Dock and dockside support services for vessel load-out
- Personnel

<u>Permits and Documentation</u>

The riser contractor and downhole service contractor will support the operator in obtaining permits to install the riser on the tree.

Procedures, Offshore Maintenance Plan, and a Safety Plan for riser installation are prepared by the SSR installation contractor for approval by the client. Procedures are to include details for preparation and use of the SSD and active deck equipment, including steps for hydraulic fill and bleed and function testing. Procedures are to detail deck handling of components, operation of the riser assembly and deployment system (RADS), and contingency operations in the event of closing weather window, equipment failure, or other interruption.

Certifications for riser components and handling aids are to be provided by the equipment suppliers. The riser contractor provides engineering and QC documents associated with SSR installation including drawings, torque specifications, component traceability by serial number, and modeling results for riser performance in the anticipated current profile.

The installation contractor, in cooperation with the vessel owner, is to obtain approval from the vessel classification agency for the deck fastening and load test plan.

Each contractor involved in operations is to have an approved safety program. In addition, a safety plan specific to mobilization and offshore operations for the particular task is to be submitted for review and comment. All relevant Material Safety Data Sheets (MSDS) shall be provided along with the safety plan.

The QC plan for installation shall include inspection requirements and standards, record keeping requirements, testing requirements with pass / fail criteria, and details of requirements for verification of as-left conditions including valve positions and connection interfaces. Qualification and training requirements for offshore personnel shall be included in the QC plan.

A detailed mobilization plan is required and must include a deck layout drawing with sufficient detail to show routing of electrical cables, lines for hydraulics and other fluids, and protective covers where these lines cross walkways or equipment thoroughfares. The mobilization plan is to include equipment lists and checklists for items to be loaded onto the vessel and for all necessary dockside activities.

Components of the SSR and structural casing riser extension

Each item shall be permanently marked with a part number and serial number to be used in the installation tally and also used for cross reference to records from manufacturing, testing, inspection, and prior use. All active items shall be function tested before mobilization and all interfaces shall be subjected to fit check as part of System Integration Test.

All riser components required for the specific job are to be staged at the dock. Each item must be protected at all times from the environment, temperature extremes, tampering, and loss or damage. All items are to be staged in baskets or bolsters marked with maximum weight and suitable for lifting and offshore use. Slings with current certification records are to be provided for each item.

Equipment Spares and Consumables for SSR Installation

Special equipment is required to enable a work boat or light construction vessel to run riser joints, buoyancy modules, and other elements of the riser. This includes a hydraulic power unit; vans for controls, spares and tools; and the riser assembly and deployment system (RADS). The RADS includes tongs, slips, moonpool guides, and associated equipment to restrain joints and heavy equipment as they are moved on deck. Compressors and / or liquid nitrogen are required for de-ballasting the riser buoyancy.

Spares and tools per the Offshore Maintenance Plan must be staged and shown to be ready. Spares and tools suitable for repair of all active components should be included to the extent that offshore repair is not precluded by vessel motion, environmental factors, or safety considerations associated with shipboard operations.

Consumables, such as pipe dope, coating repair kits, and hydraulic fluids, may require special handling and storage if flammable, toxic, or detrimental to the environment.

Vessel with Fuel and Consumables

The vessel must be U.S. flagged to comply with Jones Act requirements for transporting the riser without an intermediate stop in a foreign country. Training and license status for key vessel personnel must be verified.

The vessel survey must be completed to confirm adequacy and appropriateness of onboard equipment and safety features, and compliance with all requirements of the applicable classification agency, the United States Coast Guard (USCG), and the client. Certification of cranes and lifting devices must be verified, including recent load tests, condition of safety brakes and stops, and suitability for the particular requirements of SSR installation and recovery.

The DP system shall be surveyed for function and condition of thrusters, engines, generators, and controls. The deck structure, particularly around the moonpool, must be surveyed to verify load capability. The vessel survey also includes suitability of accommodations, communications, and navigation equipment. The ROV system requires a survey to verify load test of launch and recovery system, ROV condition including spares, availability and condition of tools, etc.

The vessel must be adequately fueled and provisioned before sailing. There must be provisions for refueling any engines used on deck.

Dock and Dockside Support for Vessel Load-out

Dock facilities must be mutually agreeable to the key stakeholders. Considerations include location, water depth, safety record, security, dock conditions, and availability of dockside services. Required services include provisions for staging equipment and lifting equipment from trucks and onto the vessel, supply of fuel and potable water, and basic yard functions such as welding and non-destructive testing.

Storage is required for any vessel item that cannot remain onboard during riser installation.

A suitable shore crane with appropriate certification is needed for unloading trucks and lifting equipment to the vessel. Welding services and non-destructive test services are required for sea-fastening of equipment.

Personnel

All personnel required for vessel mobilization and offshore operations must be qualified, contracted, and made available at the dock along with their tools and supplies. This includes welders, nondestructive testing technicians, and offshore personnel including representatives for the manufacturers of the tree and the active SSR components.

Personnel must be verified to have suitable safety training, Transportation Worker's Industry Credential (TWIC) cards, and any special certifications required by the vessel or the operator.

Load-out And Sail Away

The vessel has the highest day rate of the items required so all other items should be staged and ready when the vessel arrives at the dock.

A preliminary listing of equipment with weights and dimensions is shown in Table E1.

Table E1
Preliminary Equipment List for Vessel Load-out

Equipment Item on Construction Vessel	Outline Dimensions on Deck	Weight
Riser joints 6 5/8 in drillpipe	2 ft w x 4 ft h x 32 ft long rack per 1000 ft depth	33,000 lb per 1,000 ft depth
Buoyancy modules	16 ft h x 14 ft OD	21,000 lb each
RADS	30 ft h X 28 ft X 28 ft	TBD
SSD and tree interface	TBD	
HPU for SSD and tree	8 ft h x 8 ft w x 20 ft	20,000 lb

Table E1 Preliminary Equipment List for Vessel Load-out		
Equipment Item on Construction Vessel	**Outline Dimensions on Deck**	**Weight**
Stress joint / isolation valve / connector assembly	40 h x 5 ft w x 5 ft L	TBD
Underwater CT BOP	15 ft h x 5 ft x 5 ft	40,000 lb
HPU for CT BOP	8 ft h x 8 ft w x 20 ft	20,000 lb
Control umbilical for SSD and tree with connectors and installation equipment	25 ft h x 25 ft l x 8 ft reel	100,000 lb for 10,000 ft
Umbilical reel for air hose for buoys	TBD	
Test line and pump for SSR pressure test	TBD	
Vans for controls and spares	8 ft h x 8 ft x 20 ft	TBD
Gas supply for buoys	8 ft x 12 ft	
Consumables including pipe dope, cleaning fluids, coating repair kit, and hydraulic fluid	6 ft h x 8 ft x 8 ft	3,000 lb
Specialty PPE		
DP beacon		
ROV tools for function and override of SSD and connectors		
Clips for sea fastening		
QC inspection aids		
Riser extension joints		

Vessel load-out is to be supervised by the installation contractor with oversight by the Client Representative. Representatives of all key contractors are to participate to ensure that their equipment is handled properly and left in fully operable condition.

The RADS is the heaviest single lift for mobilizing the SSR installation vessel. This unit provides the tools and equipment required to assemble the SSR.

Table E2 presents a high level overview of procedural steps for mobilization, beginning with all equipment staged at the dock and ending with the vessel loaded and provisioned.

Table E2 Installation Vessel Load-out Procedure	
Step	**Vessel Load-out Activity**
1	Inspect vessel for acceptance. This may include DP trials, vessel general condition, safety gear, and other items per requirements of USCG, the client, and insurance carriers. Review adequacy of communications systems, fuel, lubricants and provisions. Plan to take on supplies as needed.

Table E2 Installation Vessel Load-out Procedure	
Step	**Vessel Load-out Activity**
2	Board crew for equipment load-out. Hold kickoff meeting and safety briefing for personnel involved in load-out. Verify that all appropriate MSDS are readily available onboard.
3	If necessary, offload any vessel equipment that is not needed for SSR installation to free up deck space or provide access or improve safety.
4	Lift RADS and set it over the moonpool. Remove and stow the lifting slings.
5	Obtain hot work permit and begin welding sea fastening clips, starting with the RADS frame and continuing as additional equipment is loaded.
6	Use deck crane to temporarily install moonpool guide rails and fit check rails to walls of moonpool. **CAUTION**: Vessel should not maneuver in shallow water while guide rails are installed. Guide rails are to be removed and stowed prior to vessel transit.
7	Lift HPU, control van, and spares van from dock and sea fasten.
8	Lift and set consumables pallets on deck and sea fasten.
9	Connect hoses and cables for RADS. Install safety covers over lines, inspect whip checks.
10	Fill and bleed hydraulic lines and fill HPU fuel tank.
11	Function test active features of umbilical reel drive and RADS including moonpool cover, tongs, etc while proceeding with other mobilization tasks.
12	Lift and sea fasten SSD and tree interface assembly. **NOTE**: This assembly can be set on the moonpool cover to avoid deck handling while the vessel is offshore.
13	Lift and set umbilical reel(s).
14	Connect umbilical to HPU and control consoles. Test controls functions for SSD via consoles and umbilical.
15	Lift and sea fasten riser joint racks with joints.
16	Lift and sea fasten seafloor stress joint / connector assembly.
17	Lift and sea fasten other specialty joints that cannot be stowed in the rack with the standard joints.
18	Lift and sea fasten buoyancy modules.
19	Lift gas supply equipment and sea fasten.
20	Connect and test gas supply system.
21	Lift and sea-fasten other equipment on the manifest.
22	Finish third party verifications, including NDT of sea-fastening welds, any load tests, etc.
23	Verify suitable window for weather and sea state.
24	Board any offshore personnel not yet onboard.

Table E2 Installation Vessel Load-out Procedure	
Step	**Vessel Load-out Activity**
25	Verify that all mobilization checklists have been completed and vessel has been fueled and provisioned.
26	Dismiss all personnel who are not required offshore.
27	Cast off and motor to site.

SSR Installation Procedures

Offshore operations are to be supervised by the installation contractor with oversight by the Client Representative. Table E3 is a high level overview of procedural steps prior to start of installation work.

Table E3
On-site Preparatory Operations

Step	Vessel Activity
1	Notify host platform of arrival.
2	Perform DP checks.
3	Dive ROV for ‘as found’ inspection of tree and associated infrastructure and for measurement of current in water column. Set acoustic beacon for DP.
4	Plan riser assembly location with respect to tree location.
5	Hold kickoff meeting and safety briefing for installation crew.
6	Verify that weather window and current forecast are suitable for SSR installation.
7	Perform pre-installation checklists for equipment, including activation and function test of hydraulic power units, RADS, control consoles, umbilical reel drive, and gas supply system. Install guide rails in moonpool.
8	Take up station, preferably 20% of water depth from seafloor infrastructure to mitigate dropped object hazard to tree, flowline, etc.

Figure E1 shows the general arrangement of components in the SSR.

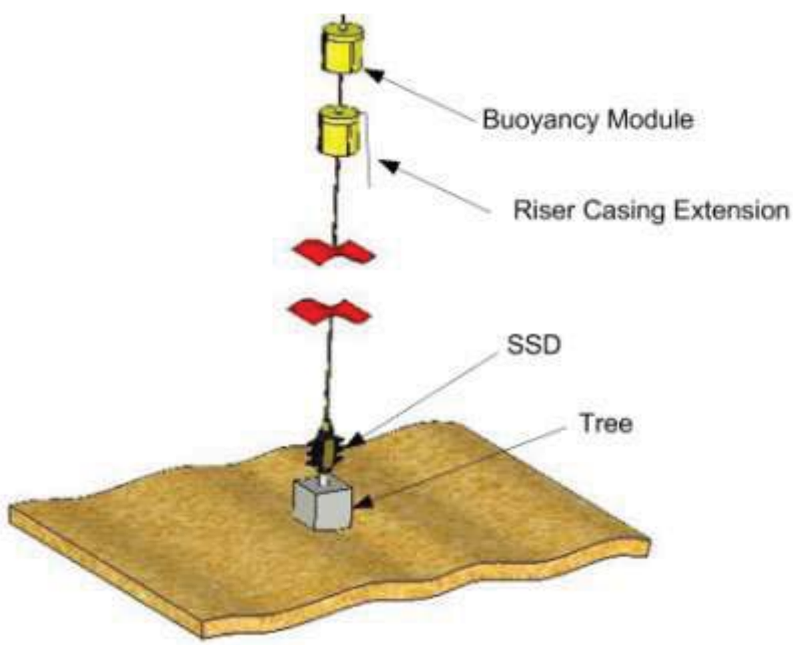

Figure E1
Equipment Locations in Typical SSR Assembly

Assembly of the SSR is to be supervised by the installation contractor with oversight by the Client Representative. Table E4 is a high level overview of procedural steps for assembling the SSR and making it ready to relocate to the tree or a temporary anchor. Representatives of all key contractors are to participate to ensure that their equipment is handled properly and left in fully operable condition.

The steps can be reversed at any point to recover the SSR if installation cannot be completed due to closing of the weather window or other problems.

Table E4
Assemble SSR from 6-5/8 in Drillstring or Casing

Step	SSR Assembly Activity
1	Release sea fastenings and the transfer the tree interface / SSD assembly to the RADS. NOTE: This is the heaviest assembly, and it can be set in the RADS at the dock to reduce the requirements for offshore handling of equipment.
2	If the stress joint is not already attached to the SSD, lift stress joint / connector assembly and engage the connector to the top of the SSD.
3	If umbilical is to be installed with the SSR, feed tree control umbilical through umbilical guide on RADS and connect to SSD
4	Function test SSD through umbilical.
5	Verify that SSD valves are left in correct position. Valves are normally left open to allow riser to flood as it is assembled and lowered.
6	Inspect and test to verify readiness of controls connector for ROV installation of umbilical jumper to tree.
7	Use HPU and control panel to charge SSD accumulator to at least seafloor ambient seawater pressure to avoid negative pressure on accumulators.
8	Use winch wires or crane to lift SSD clear of the moonpool cover and open moonpool cover.
9	Lower SSD into moonpool while paying out umbilical.
10	Close moonpool cover around upper part of stress joint and hang stress joint below moonpool cover.
11	Upend next joint, secure to RADS cross bar, and land joint in box of stress joint assembly.
12	Close tongs and thread joint to stress joint assembly.
13	Inspector is to record data on connection and tally the serial number of the joint.
14	Open tongs and slips and use crane to lower assembly while paying out umbilical.
15	Hang assembly in slips.
16	Use ROV to release winch wires (if used) and recover wires
17	Repeat above joint installation steps to install subsequent drill string joints. ROV with banding device may be used to secure umbilical to joints as they are lowered.
18	Continue per engineering documentation until the required number of joints has been installed below the lowest buoyancy module.

Table E4 Assemble SSR from 6-5/8 in Drillstring or Casing	
Step	**SSR Assembly Activity**
19	Transfer a buoyancy module to the RADS, using equipment to prevent module motions with respect to the vessel. Use supports on the moonpool cover to align buoy's guide sleeves with the moonpool guide rails.
20	Remove handling equipment and attach winch wires to buoyancy module.
21	If the joint that goes through the buoy was not previously installed, lift it and secure it in the joint guide on the cross bar of the RADS, and lower buoy joint into the central sleeve of the buoy and land its pin in box of previous joint.
22	Close tongs and make up threads between buoy joint and previous joint.
23	Open tongs and disconnect crane line.
24	Inspect buoy and update tally with serial numbers of buoy and buoy joint.
25	Lift assembly with winches and release slips.
26	Open the moonpool cover. Verify guide sleeves on buoy are engaged to guide rails in the moonpool.
27	Lower assembly on winch wires while paying out umbilical.
28	Close moonpool cover and hang assembly in slips.
29	Repeat steps above for any drill string joints between buoyancy stations. Use acoustic telemetry or ROV to monitor buoy and buoyancy. Monitor buoyancy instruments as module is lowered and use ROV deployed hose to de-ballast buoyancy. Caution: Proper de-ballasting is required while lowering. The submerged weight of the riser will increasing as the gas in the buoys is compressed due to lowering. De-ballast as appropriate to keep the assembly heavy in water while preventing suspended load from exceeding the rating of the lowering system.
30	Repeat above buoyancy module installation steps for station 2 buoys.
31	As components are assembled and lowered, continue to pay out umbilical for SSD / tree and continue to de-ballast buoys while monitoring the instruments.
32	Install uppermost buoy(s) per buoy installation steps above.
33	Secure tree control umbilical to top buoy.
34	Use winch wires to lower assembly until submerged below wave zone and hold with lower end of SSR above seafloor infrastructure. ROV to observe lower end of SSR to ensure adequate elevation above potential interference.

Figure E2
Assembling Uppermost Buoy to the SSR

The steps in Table E4 are fully reversible for recovery of the SSR. The steps can be reversed at any time during assembly to recover the components of a partially assembled riser in the event of a closing weather window or other problems that might interrupt the installation.

Table E5 is a high level overview of procedural steps for maneuvering the assembled SSR from the assembly location to the tree, connecting the SSR to the tree, and completing required testing. The SSR can be relocated from the tree by reversing these steps.

If the tree is not ready for the riser, or if the operator prefers, the SSR installation vessel can connect the SSR to a temporary anchor. The intervention services vessel can then follow these steps to relocate the SSR to the tree. The intervention vessel can also use these steps to relocate the SSR from one tree to another or relocate the SSR to a temporary anchor when down-hole work is completed.

Table E5 Relocating and Testing Assembled SSR	
Step	**SSR Relocation and Test Activity**
1	Review current profile and plan DP move to tree location.
2	Notify host platform of readiness to land and engage the riser.
3	Verify that tree has been shut in and made ready for removal of the tree cap and connection of the SSR.
4	Request and receive Lock-Out-Tag-Out certificate from host platform showing that tree has been made safe for entry and that swab valve is closed.
5	Use ROV to remove tree cap and inspect interface for the SSR.
6	Check instruments to verify that hook load on winch wire(s) is appropriate for relocating and landing SSR. Trim buoyancy if necessary.

Table E5 Relocating and Testing Assembled SSR	
Step	**SSR Relocation and Test Activity**
7	With SSR held at a safe elevation above the seafloor by winch wire(s) or heave compensated crane wire, begin DP move along safe route to tree.
8	Use ROV to guide connector on bottom of the SSD onto tree hub and close and latch connector.
9	While SSR buoyancy is ballasted to make riser heavy in water, test connection to tree by pulling with lift wire(s) to tension SSR to standalone tension.
10	De-ballast SSR to standalone tension while slacking tension in lift wire(s).
11	Disconnect lift wire(s).
12	Pay out umbilicals while moving vessel to standoff location for final testing of SSR.
13	Increase SSR tension for ultimate load test by de-ballasting buoyancy until SSR tension is typically 1.25 to 1.5 times maximum operational tension. .
14	Hold at load test tension for required time and then ballast to operational tension in SSR.
15	Use ROV to connect pressure test line to connector cap atop SSR.
16	Fill SSR with fluid (if not already filled) and then pressurize SSR for internal pressure test. Hold till pressure is shown to stabilize. Perform ROV video inspection of SSR during pressure test. NOTE: If test is being done with SSR connected to tree, coordinate with host platform and verify that Seafloor Shutoff Device (SSD) is open so that pressure test will be done against swab valve, thus also testing the connection between the SSR and the tree.
17	Depressurize SSR and trim buoyancy to survival condition. Use ROV to measure water depth to connector hub on top of riser.
18	Close SSD valves to isolate SSR from tree. Charge SSD accumulators to 3000 psi above ambient pressure (3015 psia plus ambient seawater pressure).
19	Use ROV to disconnect pressure test line from SSR and recover the line.
20	Use ROV for ‘as left’ inspection of tree and riser.
21	Terminate umbilical with protective sealing caps, attach buoys, and secure and abandon upper ends of umbilicals.
22	Proceed to assemble and wet park riser extension per procedure below, or recover acoustic DP beacon and notify host platform of readiness for departure and prepare deck for vessel transit.

The structural, casing segment of the riser extension can be assembled by the SSR installation vessel and wet parked by hanging it from a buoyancy module of the SSR, per the steps in Table E6.

Table E6 Steps to Assemble and Wet Park Structural Riser Extension	
Step	**Riser Casing Extension Assembly and Wet Park Activity**
1	With SSR secured to tree or anchor, take up station 20% of water depth away from SSR and seafloor infrastructure to reduce dropped object hazard.
2	Lift the lowest joint of the structural casing segment of the riser extension (including connector) and set it in Riser RADS with upper part secured in joint restraint of cross bar.
3	Test the ROV operable connector and prepare connector for deployment.
4	Lift the joint with crane, open moonpool cover, lower connector and joint into moonpool, close moonpool cover, and hang joint in slips.
5	Lift next joint of riser extension, secure it in joint restraint of RADS crossbar, and use tongs to thread it to the previous joint.
6	Repeat above step for additional joints as required by documentation.
7	Lift riser extension joint that has syntactic foam and set it in RADS for assembly, thread with tongs, open moonpool cover, lower assembly, close moonpool cover, and hang assembly in slips.
8	Lift upper most joint of riser extension to RADS and use tongs to thread it to the assembly. Total length of extension is to suit as-installed depth of the SSR.
9	Secure top of riser extension to line from constant tension winch, and lower to hang-off depth.
10	Maneuver vessel on DP to position the riser extension near the SSR.
11	Maneuver vessel and use ROV assistance to guide the extension to the attachment location on the buoy.
12	Use ROV to secure the top of the riser extension to the buoy and secure the bottom of the riser extension to the casing.
13	Use ROV to release lowering line from the riser extension and recover wire.
14	Use ROV to inspect the riser extension and upper part of SSR.
15	Notify host platform of readiness for departure, recover DP beacon, and prepare deck for vessel transit.

MOBILIZATION PROCEDURES FOR INTERVENTION

If separate vessels are used for SSR installation and intervention, the equipment addressed in this section does not need to be mobilized until after the SSR has been installed. The mobilization procedures for installation and intervention can be worked in parallel if a suitable single vessel is used.

Preparatory Work for Down-Hole Intervention

The CT service contractor will provide the CT equipment and associated personnel. Preparations specific to reentry and work-over will be coordinated by the down-hole service contractor including engineering, detailed procedures for down-hole work, vessel selection and related deliverables. Primary categories of preparation are:

- Permits, procedures, certifications, safety and QC plans, and engineering documentation
- Preparation of equipment that interfaces to the SSR
- Preparation of CT equipment and consumables
- Vessel with supplies, provisions, and fuel
- Dock facility and dockside support
- Personnel

Permits and Documents

The riser contractor will support the operator and down-hole service contractor in obtaining permits. Procedures, an Offshore Maintenance Plan, and a Safety Plan are provided by the down-hole service contractor and approved by the client. The riser contractor will assist in preparing procedures that involve interface to the SSR. Contingency operations for use in the event of a closing weather window or other interruption are to be detailed.

Deck arrangements, deck loading, and the sea fastening plan are to be approved by the vessel classification agency and submitted to the client.

A mobilization plan is needed for the items discussed herein and should include a deck layout drawing with sufficient detail to show routing of electrical cables, hydraulic hoses, other fluid lines, and protective covers where these lines cross walkways or equipment thoroughfares. The mobilization plan is to include checklists for dockside activities and for all items to be loaded onto vessel.

Interfaces to the SSR

The SSR interface equipment consists primarily of the MIS and the emergency disconnect segment of the riser extension.

The emergency disconnect segment includes the near-surface shear and seal device, the emergency disconnect connector, and the retention valve for the riser extension. This assembly is preferably prepared and tested onshore. It is installed by the intervention vessel so that it can be recovered for maintenance during down-hole operations.

The baseline configuration and plan calls for the structural casing extension to be wet parked by the SSR installation vessel as part of the riser installation. Alternately, it can be assembled by the CT vessel.

CT equipment and consumables

The injector, CT reel, pumping equipment, and other items of CT equipment are mobilized to the intervention vessel. The CT choke and kill lines, if used, are preferably reeled. Other CT equipment can be used in the same configuration it would be operated from a production platform and routine preparations are appropriate. The need for cement or other consumables such as drilling fluids depends on the specific tasks to be done. The intervention vessel is expected to have bulk storage tanks suitable for the necessary consumables.

Vessel with supplies, provisions, and fuel

The vessel survey for adequacy and appropriateness of onboard equipment and safety features, and for compliance with requirements of the applicable classification agency, the USCG, and the operator client, must be current. Training and license status for key vessel personnel must be current.

The function and condition of the DP system including thrusters, engines, generators, and controls must be suitable for operation while attached to the client's seafloor equipment. The deck structure around the moonpool must be adequate to support the weight of the MIS, while it in turn supports the injector and deployed tubing. The ROV system must be in good condition and suitable for tasks, including work with the riser extension and umbilicals.

Dock and Dockside Support for Vessel Load-out

Key considerations in dock selection include location, water depth, safety record, security, dock conditions, and availability of dockside services. Required services include provisions for lifting and staging equipment, access to fuel and potable water supply, and basic yard functions such as welding and nondestructive testing.

The shore crane rating must be adequate for lifting the CT reel to the deck of the vessel. This crane can also be used to lift the fully assembled MIS and the other CT equipment, which is much lighter. Deck fastening clips, welding services, and non-destructive test services are required for sea fastening of equipment.

Personnel

Personnel required for installation of the MIS on the vessel consist primarily of hydraulic and electrical technicians and an engineer. Third party services are required for welding and non-destructive test of sea fastenings. In addition to personnel required by the client, a crew of five is normally required to operate the down-hole intervention equipment for 24-hour operations. Section 11 includes a tabulation of personnel used for cost estimating purposes.

Figure E3
Typical Deck Arrangement for CT Vessel

Intervention Vessel Load-out Procedure

The CT reel and the MIS are the most difficult items to mobilize. The CT reel is the heaviest lift. The MIS is lighter but requires more man-hours for installation. An overview procedure for mobilization is in Table E7.

Table E7
Intervention Vessel Load-out Procedure

Step	Vessel Load-out Activity
1	Inspect vessel for acceptance. Include DP trials, vessel general condition, safety gear, and other items per requirements of USCG, the client, and insurance carriers. Review adequacy of communications systems, fuel, lubricants and provisions. Plan to take on supplies as needed.
2	Board crew for equipment load-out. Hold kickoff meeting and safety briefing for personnel involved in load-out. Verify all appropriate MSDS are readily available onboard.
3	Use dock crane to lift MIS and set it over moonpool. Remove and stow the lifting slings.
4	Obtain hot work permit and begin welding sea fastenings, starting with the MIS frame and continuing as additional equipment is loaded.
5	Lift and sea fasten MIS HPU and van for controls and spares
6	Connect MIS power and control lines. Install safety covers where lines cross walkways and inspect whip checks.
7	Fill and bleed hydraulic lines, fill HPU fuel tank, and function test the MIS.
8	Lift jumper reels and sea fasten.
9	Connect reel power and controls. Test reel drives.
10	Lift gas supply equipment and sea fasten.
11	Connect and test gas supply system.
12	Lift and sea fasten CT reel drive and reel.
13	Lift and sea fasten HPU for CT equipment.
14	Lift and sea fasten injector.
15	Lift and sea fasten preassembled emergency disconnect segment of the riser extension. This segment includes the near-surface shear and seal, the emergency disconnect connector, the blind shear retention valve, and end connectors.
16	Finish third party verifications, including NDT of sea fastening welds, any load tests, etc.
17	Lift and sea fasten packer stripper and diverter.
18	Take on consumables and vessel supplies.
19	Verify suitable window for weather and sea state.
20	Board any offshore personnel not yet onboard.

Table E7 Intervention Vessel Load-out Procedure	
Step	**Vessel Load-out Activity**
21	Verify that all mobilization checklists have been completed and vessel has been fueled and provisioned.
22	Dismiss all personnel who are not required offshore.
23	Cast off and motor to site.

Onsite Activity for Down-Hole Work

This section covers offshore work for down-hole operations and is limited to those aspects that differ from CT work from a platform. Down-hole operations are considered in this report to the extent that they interface with the riser, the vessel, or deck equipment. Aspects of down-hole operations that relate only to conventional CT equipment and tools, or are unique to specific downhole tasks, are beyond the present scope.

For this section, it is assumed that the riser extension will be used and that the structural casing extension has been hung off from the SSR buoyancy as part of riser installation. The extension can alternately be assembled by the intervention vessel. Some CT equipment configurations do not require a riser extension.

Figure E4 is representative of the well-site configuration when the intervention vessel arrives. The first activity of the intervention vessel is to install the riser extension and install or connect the control umbilical. Appropriate tests are conducted and the intervention vessel then trims SSR buoyancy to intervention condition.

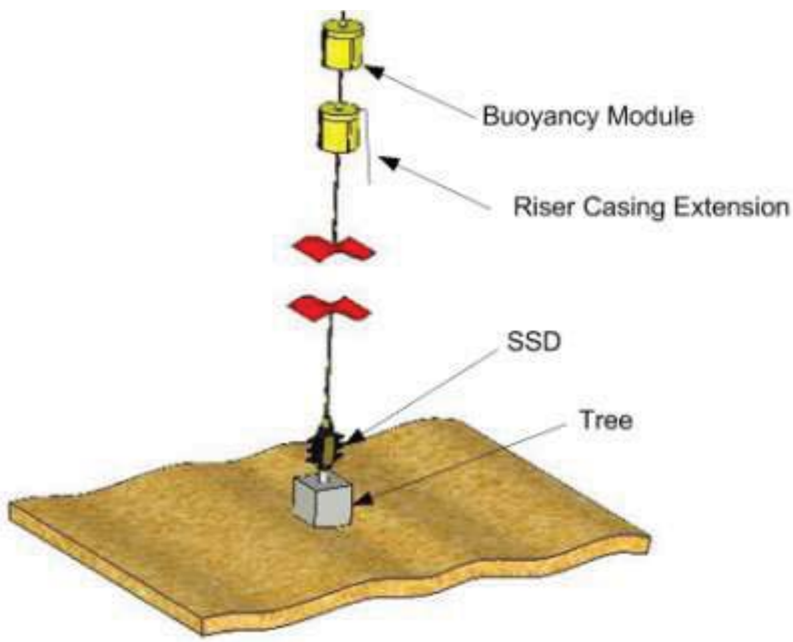

Figure E4
SSR as Found by Intervention Vessel

Table E8 On-site Preparatory Operations	
Step	**Vessel Activity prior to Down-Hole Operations**
1	Notify host platform of arrival and arrange for transfer of control of the tree and well.
2	Hold kickoff meeting and safety briefing for crew.
3	Perform DP checks.
4	Dive ROV to check current profile and set acoustic beacon for DP.
5	Use ROV for ‘as found’ inspection of SSR, tree and local infrastructure. Observe and record status of all indicators on SSD, tree, and CT BOP.
6	Verify that weather window and current are suitable for planned tasks.
7	Work off checklists for deck equipment, including activation and function test of hydraulic power units, MIS, control consoles, gas supply, and other deck equipment.
8	Install or connect umbilical for control of tree and SSD. NOTE: Umbilical may have been preinstalled by the SSR installation vessel, in which case the upper end is to be connected to the vessel as part of system activation.
9	Connect umbilical and conduct deck tests for the emergency disconnect segment of the riser extension.
10	Lift the emergency disconnect segment of the riser extension and lower it, preferably by using the crane to lower it over the rail.
11	Maneuver vessel on DP2 to take up station over the SSR.
12	Lower the emergency disconnect segment while paying out umbilical and use ROV to guide it to the hub atop the SSR.
13	Use ROV to close connection between the SSR hub and the emergency disconnect segment.
14	Close the Near-surface Shear and Seal and pressure test SSR to verify integrity of the connection to the SSR.
15	Lower lift line from constant tension winch and use ROV to secure it to the structural casing segment of the riser extension. NOTE: It is assumed that the structural casing segment was hung from an SSR buoyancy module as part of SSR installation.
16	Use ROV to unlatch the structural casing segment of the riser extension from SSR.
17	Lift upper end of the structural casing segment of the riser extension through the moonpool and hang it from the MIS. Connect packer stripper and diverter to the top of the structural casing segment. NOTE: If SSR has been relocated the water depth may be different. If so, hang riser extension in MIS and use deck crane to add or remove pup joints as required.
18	Use lift line to lower structural casing segment and use ROV to guide it to the hub atop the emergency disconnect segment which was installed previously.
19	Land the structural casing segment of the riser extension on the hub and use ROV to latch connector.

Table E8 On-site Preparatory Operations	
Step	**Vessel Activity prior to Down-Hole Operations**
20	Bring SSR to vertical by maneuvering vessel to coordinates of tree while maintaining specified tension in the winch line.
21	Adjust MIS to mid-stroke and secure riser extension to the MIS.
22	Transfer the tension to the MIS and disconnect the lift line.
23	Increase hydraulic pressure to load test the riser extension and connector. (SSR was previously load tested to higher tension.) Then adjust tension to nominal for operations.
24	Use ROV and umbilical reel drive to install tree / SSD control umbilical if it was not installed by SSR installation vessel.
25	Use ROV and gas line to trim buoyancy of SSR to operational tension in SSR.

Figure E5 shows the system following connection of the riser extension and hoses and landing the injector on the MIS.

Figure E5
System Ready for CT Operations

Table E9 below includes steps to engage the CT deck equipment to the riser and make ready for entry through the tree. Details of the procedure will depend on the specific tasks required by the project. Vessel motions relative to the SSR are the primary difference from onshore CT operations.

Table E9 Down-hole Intervention Operations	
Step	**Connection to SSR and Downhole Operations**
1	Use deck crane to set injector and connect it to the stripper packer which was attached to the riser extension previously. Connect hydraulic lines and function test the injector. NOTE: For horizontal trees, coordinate with host, balance pressure, and then use wire line to retrieve crown plugs from tree. Plugs for production tubing sizes up to and including 4 inches may be pulled through 6-5/8 in drill pipe SSR. All other components of the baseline riser are suitable for pulling crown plugs for 5 in production tubing, but the 6-5/8 in drill pipe must be replaced by larger casing if it is necessary to pull crown from a tree with 5 in production tubing.
2	Use deck crane to hang tools and feed tubing into the injector.
3	Run CT through stripper packer and down to the SSD.
4	Circulate appropriate fluids to flush water from SSR as necessary to establish pressure balance or prevent hydrate formation.
5	Coordinate with host for handover of tree control.
6	Use ROV to connect control umbilical jumper from the SSD to the tree.
7	Conduct appropriate tests and proceed to enter tree and run tubing for down-hole work.
8	Continue down-hole work to completion. For interruptions and contingencies, see Contingency and Optional Scenarios procedures below.
9	When down-hole operations are complete, pull tubing to just above SSD, close swab valve in tree, and close SSD to isolate SSR from tree. NOTE: For horizontal trees, replace crown plugs before closing SSD and flushing riser.
10	Use ROV to recover umbilical jumper which was installed previously between SSD and tree.
11	Circulate fluids from riser as appropriate and return control of the tree to host.
12	Recover tubing to the CT reel and close the near-surface shear and seal.
13	Lift injector off MIS, disconnect the riser extension, and wet park structural casing segment of riser extension by reversing the installation steps.
14	Use ROV and lift line to recover the emergency disconnect segment of the riser extension from atop the SSR and replace cap on the top hub of the SSR.
15	Use ROV for as-left inspection of SSR and tree.
16	Notify host platform of readiness to depart, recover DP beacon, and prepare deck for vessel transit.

Contingency and Optional Scenarios

Routine disconnection is accomplished by pulling the tubing from the SSR, closing the tree and / or SSD and the near-surface shear and seal, disconnecting the upper part of the riser extension from the SSR, and hanging off the tree / SSD control umbilical. The vessel is then free to motor to the host platform or run from weather. It is not necessary to wet park the riser extension on the SSR prior to maneuvering on DP for tasks such as making vessel to vessel transfers at a safe distance from the seafloor infrastructure.

Table E10
Routine Disconnection of Intervention Vessel

Step	Steps FOR Routine Disconnection of Intervention Vessel
1	Pull tubing from well.
2	Notify host platform of intent to disconnect from riser.
3	Close Seafloor Shutoff Device or tree valves.
4	Pull tubing from riser.
5	Close the near-surface shear and seal device.
6	Disconnect tree / SSD umbilical at the surface. Cap the umbilical, attach buoyancy, and abandon umbilical.
7	Close the retention device at the lower end of the riser extension and disconnect riser extension from the SSR. **NOTE**: At this point the vessel is free to maneuver on DP for objectives such as making transfers at a safe distance from the tree. Proceed to the following steps before making an extended transit.
8	Position ROV to assist with wet parking the riser extension.
9	Attach line to the top of the riser extension, take load on the line, and release riser extension from MIS.
10	Use ROV to disconnect the structural casing segment of the riser extension from the active segment, lift structural casing extension clear of the SSR, and maneuver vessel. Disconnect the return line from diverter and wet park riser extension on the SSR by reversing the steps used earlier to connect the extension between the SSR and the vessel.
11	Perform ‘as-left’ inspection, recover ROV, and depart.

Emergency disconnection may be necessary in an extreme event such as DP drive off or fire on board. The following steps should be initiated in sequence, but there is no need to complete any step before proceeding to the next step.

Table E11 Emergency Disconnection From Well	
Step	**Steps for Emergency Disconnection**
1	Close the SSD immediately if an emergency disconnection is ordered. The SSD will sever the tubing, if present, and isolate the SSR from the reservoir.
2	Close the near-surface shear and seal. This will shear tubing, if present.
3	Close the blind shear retention device at the lower end of riser extension and release the connector that secures the riser extension to the SSR. **NOTE**: Above steps will remove load from MIS. This will cause the MIS to stroke up and lift connector clear of the SSR. **NOTE**: These steps shear the tubing on both sides of the emergency disconnect connector, thus providing redundant release of the vessel from deployed tubing to ensure disconnect from the riser.
4	Disconnect and abandon the umbilicals. **NOTE**: The above steps fully separate the vessel from the SSR.
5	Take action appropriate to the emergency and notify host platform of incident.

Table E12 Move Riser from Tree to Tree	
Step	**Steps for Relocation of SSR by Intervention Vessel**
1	Verify that work on previous well has been completed, that CT has been pulled from riser, that SSD is closed and reservoir is contained by the tree, and that control of tree has been returned to the host. Verify that SSR buoyancy is in standalone condition, per engineering documentation.
2	Coordinate with host platform on plans to relocate the SSR.
3	Close SSD and the near-surface shear and seal device.
4	Attach line to the top of the riser extension and release structural casing segment of the riser extension from MIS.
5	Tension line while ballasting buoyancy to make SSR heavy in water, per engineering documentation.
6	Verify that SSR buoyancy is properly ballasted and then disconnect SSD from tree.
7	Lift riser clear of the tree and other seafloor infrastructure.
8	Maneuver vessel to the tree to which riser is to be moved. . **NOTE**: If water depth is significantly different it will be necessary to add or remove joints of the riser extension.
9	At the new well site, inspect the tree and remove the tree cap per appropriate steps of riser installation procedure *SSR Relocation and Test Activity*
10	Maneuver vessel on DP, adjust elevation of SSR, and position SSR above tree

Table E12 Move Riser from Tree to Tree	
Step	**Steps for Relocation of SSR by Intervention Vessel**
11	Repeat appropriate steps of SSR installation procedure to land SSR on tree, latch connector, and hook up controls to tree.
12	Repeat pressure test and load test of SSR, as appropriate to test connection to new tree.
13	De-ballast SSR buoyancy to operational condition.

System Level Offshore Maintenance

The need for offshore maintenance is reduced by emphasizing onshore preventive maintenance, redundancy, conservative design margins, and short service duration. Offshore maintenance consists of repairs and routine preventive maintenance that cannot be done onshore.

During installation of the SSR, all components can be retrieved to deck for repair or replacement.

During down-hole operations, all active components with the exception of the SSD can be recovered and repaired or replaced on the deck of any intervention vessel. A larger intervention vessel can recover the SSD by disconnecting the riser from the SSD, hanging the riser from the MIS, and then recovering the SSD with a lift line. The SSD is designed and built to high reliability and quality standards to minimize the likelihood that it will need to be recovered for repair. This is consistent with its role as the final line of defense for reservoir isolation.

The configuration and maintenance provisions discussed in this section apply to the baseline configuration. Other configurations may be used at the discretion of the downhole service contractor and the client, and maintainability is one of several considerations when choosing the configuration. A detailed maintenance plan is to be prepared prior to mobilization, and is to include a comprehensive list of spares and tools needed to maintain, repair, or replace all components.

Maintenance of Riser and Riser Installation Equipment

The SSR is designed for high reliability with minimal offshore maintenance. Equipment used to install the SSR is accessible for repair on deck, and all known failure modes can be repaired without jeopardizing the vessel or the SSR.

The SSR is a passive structure designed to standards for similar equipment in production systems intended for 20-year life without maintenance. Structural failure early in the life of such components is rare. The primary failure modes result from fatigue, corrosion, and damage, all of which tend to be cumulative over long periods. The SSR is designed for a 20-year service life but is normally installed for only a few weeks and never for more than a year or two before it is recovered, and all components are then inspected and refurbished, de-rated, or scrapped. This allows for frequent preventive maintenance onshore in a shop environment and minimizes the need for offshore maintenance.

Each component of the SSR has a serial number that is used to track its service life. A full history, including manufacturing records, qualification testing, mobilization dates, location, nature of service, and duration of each installation is to be recorded for each serial number. Records are to be updated each time the item is mobilized or recovered, and periodically if the item is idle. Items are to be taken out of service if they fail inspection and cannot be fully refurbished, or if fatigue cycles approach the allowable limit. Allowable fatigue life is known from the design and manufacturing records, and actual fatigue is calculated based on time in service, the position in the riser where the item was used, and the environmental or service characteristics that may contribute to fatigue during use.

Credible failure modes for air can buoys are primarily leaks and structural failure. As is required for surface vessels, the SSR is designed to function after unintentional flooding of any one buoyancy chamber. Specifying that the buoyancy modules have no through-hull penetrations in the top or sides reduces the risk of leakage. A liner is to provide a second barrier against loss of gas. Buoys are to be coated and have ample design margins for structural strength and corrosion allowance. Coating repair kits are to be used to repair any coating damage noted during installation.

Equipment used to install the riser is subject to a wider range of failure modes but is accessible on deck. All known failure modes are amenable to repair without risk to the safety of the vessel or the riser. For example, the suspended riser can be held by the slips, the constant tension winches, or the crane if any one of these three ways to support the load should require maintenance. Spares and tools are mobilized for offshore maintenance and repair of installation equipment. Items most likely to require offshore maintenance are the tongs, constant tension winches, hydraulic power units, and control panels.

Maintenance of Operations Equipment

The SSD and the MIS are the only elements of the CT system that are custom-built. Hydraulic components of the MIS are specified to be fully redundant so that no single failure will interrupt service and most components can be replaced while the system remains in service. The CT reel drive brake can be used to lock the reel if the hydraulic drive components require maintenance.

Because the SSD is installed by the SSR installation vessel and used by the intervention vessel, it is the only active component that is not readily accessible for maintenance during operations. In addition to the onshore preventive maintenance referred to above, the SSD is specified with redundancy and ROV override capability for all functions. Valves, controls, and other active components are used only a few times during each installation and are then available for testing and preventive maintenance in a shop environment onshore.

If the SSD controls fail, the near-surface shear and seal device can be used to contain reservoir pressure until the ROV can override the SSD. When used with a vertical tree, the tree can be used to isolate the reservoir after the tubing has been recovered or the ROV has been used to override the shear function of the SSD. If the SSD fails during work through a horizontal tree, the casing length between the packer stripper and the near-surface shear and seal device can be used to inject wireline tools to reset the crown plugs.

The intervention vessel installs all other active components, including the near-surface shear and seal device, the retention valve, and the emergency disconnect connector, all of which are in the riser extension. These components can all be recovered to the deck of the intervention vessel by reversing the installation procedure.

The SSR installation vessel hangs the structural casing segment of the riser extension from a buoyancy module of the SSR. The intervention vessel then lifts this segment and installs it above the emergency disconnect segment. As part of handling the riser extension, its upper end is lifted through the moonpool of the intervention vessel so that the diverter and packer stripper can be connected. This action can be reversed if it is necessary to rework or replace the packer stripper or the return line from the diverter. Other elements of the CT system vary only slightly from common field proven configurations, and they are on the deck of the intervention vessel, where they are accessible for maintenance.