Subsea acceleration
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Paul Hillegeist

Paul Hillegeist is President and Co-Founder of Quest Offshore Resources, Inc, which is headquartered in Houston (Sugar Land) and was incorporated in 1999. Quest Offshore is an industry leader in Market Intelligence, Deepwater Data and Consulting focused on the upstream oil & gas sector worldwide with a specialized emphasis on subsea technology, floating production and marine construction.

Paul actively leads Quest’s Research and Data Division as well as their growing Consulting Practice which supports oil companies, oilfield service companies, industrial conglomerates, leading financial firms and investment banks.

Paul has over 21 years of oil & gas industry experience including over four years as Manager Corporate Development at Global Industries and five years as Editor/Senior Market Analyst at Offshore Data Services, now ODS-Petrodata.

Paul is a 1988 graduate from The University of Texas at Austin with a Bachelor of Arts Degree in Economics. Paul has authored numerous articles in prominent industry trade journals on the global deepwater and subsea production market. Paul is an active member of the Society for Underwater Technology and the Marine Technology Society.
Foreword
It is with great pleasure that we introduce this detailed CLSA U report on the subsea sector of the oilfield services industry. We expect subsea equipment orders will almost double over the next two years as deepwater fields continue to enter production. From there, we expect the subsea market to continue to grow as drilling in deeper waters is a necessary step to grow production of hydrocarbons to satisfy increasing energy demand. Visibility of accelerating growth in the subsea market based on future major project awards has created increased confidence for companies in the subsea equipment space. We share this confidence in the medium-term growth outlook, as well as in the continuation of the long-term secular trend of a larger portion of the world’s oil and gas production coming from water depths greater than 4,000 feet.

We envision a future in which “subsea factories” will make deepwater exploration and development increasingly efficient and economically attractive. This trend will allow the subsea market to continue to be one of the oil service industry’s most interesting segments, especially as other areas of the oilfield services market have slower growth. In our view, the subsea market reflects a global secular growth story of new infrastructure and technological innovation supporting hydrocarbon developments in deepwater.

While there currently appears to be aggressive bidding activity in the subsea market for new awards, we expect backlogs for subsea equipment companies to continue to grow, eventually leading to pricing power as available capacity is absorbed. Momentum should continue to increase in the subsea market as more infrastructure on the ocean floor will make it possible to continue to connect satellite fields. Companies that already have equipment on the ocean floor for the largest field operators should benefit from this market momentum for years to come.

FMC Technologies is currently the clear market leader in the subsea equipment market. Other large companies are aggressively competing with FMC Technologies, including Aker, Cameron, GE and Technip. While these companies battle at the top, there is still room for companies with specialized technologies such as Dril-Quip and Oceaneering International.

Risks for the subsea equipment market include delays in project awards or the cancellation of large offshore projects. International and national oil companies appear committed to their largest projects, based on recent spending announcements and incremental contract bidding, creating increased visibility in 2012 and 2013. We believe the largest offshore field development projects remain less sensitive to global economic uncertainty and recent oil-price volatility. Investing in the subsea equipment space will provide investors with attractive growth opportunities for many years to come.

Mark S. Urness
Managing Director
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Drilling down
Subsea acceleration

The subsea market is poised for significant demand growth from all major deepwater regions. Subsea trees, the permanent structures deployed on the seabed on top of the wellhead to control and monitor production, are essential for deepwater extraction, and the Quest mean-case subsea tree award forecast expects over 3,200 new subsea tree awards from 2011 through the end of 2015. This figure almost matches the total number of awards from the last decade in just five years. Quest anticipates almost 40% of this future demand will occur offshore Brazil. Africa ranks second after Brazil with more than 20% of future global subsea tree demand.

The subsea market has grown considerably from its humble initiation in 1961 to being an instrumental enabler for deepwater oil and gas developments. A number of drivers influence deepwater offshore oil and gas activity, including crude oil prices, equipment and service costs, global economic activity, geopolitical issues and a lack of access to traditional oil and gas reserves.

Subsea technologies are opening remote locations for hydrocarbon production

Subsea tree awards are a leading indicator for the growth of the subsea industry. Subsea technologies, those deployed on the sea floor, are not as constrained by water depth, distance to production facility or challenging reservoir conditions. They are opening up harsh and remote locations to hydrocarbon production, which translates into additional global energy supply.

Global subsea trees by on-stream year

Subsea tree awards are a leading indicator for the growth of the subsea industry. Subsea technologies, those deployed on the sea floor, are not as constrained by water depth, distance to production facility or challenging reservoir conditions. They are opening up harsh and remote locations to hydrocarbon production, which translates into additional global energy supply.

Note: On-stream year is the year the well controlled by the subsea tree started producing oil & gas.
Source: Quest Offshore Resources, Inc

Subsea equipment required to increase global energy supply

Subsea tree awards are a leading indicator for the growth of the subsea industry. Subsea technologies, those deployed on the sea floor, are not as constrained by water depth, distance to production facility or challenging reservoir conditions. They are opening up harsh and remote locations to hydrocarbon production, which translates into additional global energy supply.

New subsea technology will allow operators to break deepwater production records

Quest expects the water depth for a subsea tree installation to continue to increase, soon exceeding the recent record for installation in 9,627 feet of water. This progression will demand new subsea technology to overcome the challenges of producing hydrocarbons in deeper water. Some of the new subsea technologies that will lead to more record-breaking accomplishments include subsea processing, boosting and separation.
Demand boom in subsea market

The subsea market is currently in a state of transition as the market is exiting a number of tumultuous years that began in 2008 and is now on the verge of a global demand boom that is expected to start in 2012 (Figure 1).

South America and the Asia Pacific region are unique in that they are the only regions that have seen overall growth in 2009-11 versus the previous three years. Main regional drivers for the increase in subsea tree demand in the future include:

- An expected step-change in Asia driven by long-distance subsea tiebacks of stranded gas fields. In addition to tree demand, these long-awaited developments will utilize hundreds of kilometres of subsea pipeline and production umbilicals, potentially providing lucrative contracts for both equipment manufacturers and installation contractors.

- Brazil is expected to lead demand for subsea trees over the next 15-plus years as Petrobras develops their pre-salt fields while maintaining their development goals in traditional deepwater fields.

- The North Sea has always been, and is expected to continue to be, a consistent base of demand. The region has been resilient to recent global events over the past three years and is expected to see increased demand over the next 18 months.

Figure 1

Global subsea tree award momentum

In 2011, subsea equipment awards were lower than in 2010 (Figure 2), with tree awards down ~20% from this time last year. This lull in activity was a result of a drop in award activity in Africa, North America and South America in 2011. Despite this lull, Quest views this trend as temporary and not an indication of long-term weakness. The Golden Triangle (West Africa, Brazil and the US Gulf of Mexico) is expected to command the majority of subsea equipment awards in the future.

Year-over-year award activity for subsea controls is down more than 40% from this time last year. This is driven by a combination of lower subsea system awards (bundled subsea trees and controls) in addition to Brazil trees earmarked for traditional fields that do not utilize subsea control modules.
Subsea manifold awards are down a modest 8%, driven in part by awards of infill trees (additional trees for an existing project) where the manifold hardware has already been awarded, as well as awards for smaller projects that do not utilize manifolds.

The global economic meltdown at the end of 2008 radically altered the momentum of deepwater project activity. Independent operators lost access to project financing to fund marginal field developments. International oil companies (IOCs) slowed development of large fields due to concerns that oil prices did not meet the threshold (hurdle rates) necessary for commercial viability. Three years later, market conditions seem ripe for IOCs to reinitiate these large developments.

Independents, meanwhile, are regaining traction with their subsea developments, but not at the same rate as the IOCs. Future growth in the deepwater oil and gas market will require stable oil prices (above US$65/barrel) and a healthy global economic environment. This will ensure oil company confidence and the financial ability to execute these capital-intensive projects. Current subsea tree award activity has been rebounding at a tempered pace since the low watermark of 2009, and is on the verge of exponential demand growth through the rest of the decade.
The subsea industry has deployed over 4,100 subsea trees ordered globally since 2000. Over 65% of that historical demand came from the Golden Triangle of West Africa, Brazil and the US Gulf of Mexico. The North Sea has been the most stable area of subsea tree demand over the past 11 years, never dipping below 60 orders per year and with most over 90. Demand for subsea trees has been relatively evenly split between international oil companies, independent oil companies and national oil companies (Figure 8).

The subsea tree and control market share between the major suppliers (Aker Solutions, Cameron International, FMC Technologies and GE Oil & Gas) has maintained its long-term pattern of Cameron and FMC Technologies winning the majority of subsea tree awards and Aker Solutions and GE Oil & Gas leading the subsea controls (Figure 5). It is common to see fluctuations over quarters and years between market-share leaders. These changes are driven primarily by the project mix awarded at any point in time, regional concentrations as well as the contracting strategies of the suppliers and, as such, are only one aspect of a supplier’s overall strengths or weaknesses.

Cameron and FMC Technologies have been the long-term leaders in subsea tree market share, receiving over 65% of global awards, driven mainly by mega-awards offshore West Africa and Brazil, accounting for over 50% of their orders. Aker Solutions and GE Oil & Gas have had strong showings in the subsea control market led, in large part, by North Sea demand.

Capital expenditures on the main equipment within a subsea project have grown considerably since 2005. Average equipment costs for subsea tree and control systems grew 90% from US$3.8m to US$7.3m. This can be attributed to more complex trees required for more challenging developments, as well as cost inflation in the oilfield services industry. Overall spending on subsea trees, controls and manifolds is expected to exceed US$15bn by 2015.
Section 1: Demand boom in subsea market

Demand for subsea trees, manifolds and control systems increasing

Cameron and FMC Technologies have, historically, garnered the majority of the market for subsea trees while Aker Solutions and GE Oil & Gas play a large role in supplying subsea control systems (Figure 6).

All major subsea tree manufacturers also have subsea processing technology solutions that they are actively developing and marketing. FMC Technologies and Aker Solutions have had the greatest success deploying major subsea processing technology with applications in both green and brown fields. Most major deepwater basins now have subsea processing technology in operation with the most active areas currently the North Sea, West Africa and Brazil.

Aker Solutions, Cameron, GE Oil & Gas and FMC Technologies continue to work alongside the major oil companies in engineering and qualifying the highly specialized equipment required to function in deep and ultra-deep water depths under extremely challenging conditions. These companies will be among those that lead the industry into the next era of subsea technology, answering technical demands that will open up some of the most challenging reserves on the planet.
Buyers of subsea equipment

Typically the international (supermajor) oil companies lead the largest, most capital-intensive projects around the world. This makes them attractive customers for equipment suppliers with the lure of high-value contracts. Cameron and FMC Technologies have the strongest market share for the top 15 oil companies in historic subsea tree demand (Figure 7).

Total's Pazflor development offshore Angola is a prime example of a recent major capital project. The project included one of the world's largest subsea contracts, which was placed with FMC Technologies in 2007 for just under US$1bn. This project not only had a large footprint in terms of subsea demand (49 subsea trees), but was also the first application of subsea separation in the region. Clearly this was a major win for FMC Technologies and a record-setting subsea development, but projects of this magnitude are not an annual occurrence. For the subsea equipment manufacturers to have long-term success, they must create valuable relationships with a diverse group of customers between the independent, international and national oil companies and be competitive in the goods and services they offer (Figure 8).
Section 1: Demand boom in subsea market

Petrobras is one of the most active users of subsea production equipment. Petrobras is in line to start ordering record levels of subsea equipment for both their pre-salt and post-salt developments (Figures 9 and 10).

### Figure 9

**South America subsea tree demand forecast versus rest of world (mean case)**

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
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<td>103</td>
<td>122</td>
<td>167</td>
<td>98</td>
<td>231</td>
<td>217</td>
<td>267</td>
<td>355</td>
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<tr>
<td>Rest of world</td>
<td>374</td>
<td>369</td>
<td>329</td>
<td>196</td>
<td>207</td>
<td>252</td>
<td>388</td>
<td>470</td>
<td>476</td>
<td>471</td>
</tr>
<tr>
<td>Brazil % of total</td>
<td>19</td>
<td>18</td>
<td>24</td>
<td>38</td>
<td>45</td>
<td>28</td>
<td>37</td>
<td>32</td>
<td>36</td>
<td>43</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

Aker Solutions, Cameron and FMC Technologies will be vying for these high-volume awards from Petrobras over the coming years. Increased activity by OGX out of Brazil is, to a much lesser extent, contributing to Brazil’s high growth for subsea production equipment. GE Oil & Gas has a frame agreement with OGX for subsea tree supply. Areas outside of Brazil that are expected to contribute to the subsea tree demand forecast include Trinidad & Tobago with some shallow-water subsea tiebacks and the frontier area around the Falkland Islands, which saw a significant exploration discovery in 2011 of Rockhopper Exploration’s Sea Lion prospect.

### Figure 10

**Forecasted subsea tree awards by operator, 2011 – 2013**

While contract values are typically less for Petrobras (~US$3m per tree compared to global average of US$5.5m per tree), the volume of trees ordered keeps manufacturing facilities full. The six supermajor oil companies led by Chevron, BP, Total, Statoil, ExxonMobil and Shell will drive large subsea orders across all regions (Figure 10). The bulk of demand for operators like Chevron, BP, Total and Shell come from West Africa, where mega projects off Nigeria and Angola hold high contract values as well as large volumes of trees, controls, manifolds and most recently advanced subsea processing technology (Figure 11).

Source: Quest Offshore Resources, Inc
### Major future subsea projects

<table>
<thead>
<tr>
<th>Operator</th>
<th>Project</th>
<th>Location</th>
<th>Potential no. of trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apache</td>
<td>Julimar</td>
<td>Australia</td>
<td>8</td>
</tr>
<tr>
<td>Inpex</td>
<td>Ichthys</td>
<td>Australia</td>
<td>22</td>
</tr>
<tr>
<td>BP</td>
<td>West Nile Delta</td>
<td>Egypt</td>
<td>17</td>
</tr>
<tr>
<td>Woodside</td>
<td>Greater Western Flank</td>
<td>Australia</td>
<td>6</td>
</tr>
<tr>
<td>Gazprom</td>
<td>Shtokman</td>
<td>Russia</td>
<td>16</td>
</tr>
<tr>
<td>BP</td>
<td>Block 31</td>
<td>Angola</td>
<td>40</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>Erha North Ph2</td>
<td>Nigeria</td>
<td>10</td>
</tr>
<tr>
<td>Hess</td>
<td>Pony</td>
<td>GoM</td>
<td>14</td>
</tr>
<tr>
<td>BP</td>
<td>Mad Dog South</td>
<td>GoM</td>
<td>33</td>
</tr>
<tr>
<td>ENI</td>
<td>Block 15/06</td>
<td>Angola</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>Egina</td>
<td>Nigeria</td>
<td>48</td>
</tr>
<tr>
<td>Tullow</td>
<td>Tweneboa</td>
<td>Ghana</td>
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<tr>
<td>BP</td>
<td>Greater Plutonio Infill</td>
<td>Angola</td>
<td>15</td>
</tr>
<tr>
<td>Chevron</td>
<td>Lucapa</td>
<td>Angola</td>
<td>18</td>
</tr>
<tr>
<td>Maersk</td>
<td>Chissonga</td>
<td>Angola</td>
<td>20</td>
</tr>
<tr>
<td>Woodside</td>
<td>Sunrise</td>
<td>Australia</td>
<td>12</td>
</tr>
</tbody>
</table>

**Total potential trees:** 309

Note: Potential US$150m+ subsea production system projects in the next 15 months, as of 30 September 2011. Source: FMC Technologies

### Subsea umbilical technology

The global subsea production umbilical market averages approximately US$700m or more each year with activity expected to exceed US$1.1bn by 2013. In 2011, steel-tubed umbilicals accounted for 65 percent of umbilicals awarded, and though this fluctuates year by year, steel-tubed umbilicals typically account for more than half of the global market demand (Figure 12).

**Steel vs thermoplastic subsea production umbilicals (SPUs) km (2000-15)**

Umbilicals are utilized to transmit control signals (whether hydraulic, electrical or fiber-data), power, data, and chemicals for flow assurance. The two main umbilical technologies are similar, apart from the type of tubes used to transmit hydraulics and flow-assurance chemicals. Thermoplastic umbilicals are exclusively supplied by Oceaneering International (Umbilical Solutions), Technip (Duco), Prysmian, MFX and JDR Cables. Steel-tube umbilical manufacturing is the purview of a highly select group of companies including Aker Solutions, Oceaneering Umbilical Solutions, Technip, Nexans, Parker Hannifin Corp (Cabbett Subsea and Scan Rope) and Prysmian (Figure 14).
While these companies design and fabricate the actual umbilicals (the highly engineered, assembled end-product). Critical components of steel-tubed umbilicals are the actual steel tubes that provide the conduits for hydraulic control fluid to control wells as well as chemicals such as mono-ethylene-glycol for flow assurance.

After several years of much needed capacity expansion through 2008, the umbilical market is presently amply supplied and there are considerable barriers to entry.
Supply chain
Trends in offshore field developments including project-type mix drive the number and diameter of steel tubes used in umbilicals, with a need for more hydraulic tubes on more complicated trees and more challenging flow-assurance situations and due to operator preference (especially on spare tubes) driving the number of tubes. This leads to a wide variance in the number of tubes regionally.

Steel tubes have traditionally been manufactured by steel companies from specialized plants, with a limited number of players dominated by Sandvik Steel supplying seamless super duplex tubes via their Chomutov plant in the Czech Republic. However, in recent years, an increasing number of new entrants have begun to participate in this market with differing steel solutions including welded super-duplex steel, zinc-clad 19D, various lean duplexes and hyper-duplex tubes.

The global umbilical market is dynamic
The umbilical market has historically been one of the most dynamic sectors of the offshore oil and gas supply chain, not only due to the inherent volatility in the oil and gas market but also to the dependence of the market on those projects with larger umbilical lengths per tree. This is especially relevant to projects that utilize long tiebacks often associated with gas projects, especially to shore (Figure 15).

While the umbilical market is somewhat volatile, the long-term trend is positive due to ever increasing needs worldwide for oil and gas coupled with declining traditional resources, which leads to increased deepwater developments both in traditional deepwater provinces and in frontier areas. With deepwater developments utilizing subsea production systems projected to ramp up over the long term, the outlook for the subsea-production umbilical market is robust. Moreover, the key market leaders Oceaneering, Technip and Aker Solutions appear well poised for the wave of orders building in 2013-15 (Figure 16).
First deployments of subsea production umbilicals utilized thermoplastic hoses. Nexans Norway introduced the first steel-tube umbilical in 1993 and the first dynamic steel-tube umbilical in 1995. Steel tubes differ from thermoplastic hoses in that they offer enhanced response times and prevent the permeation of fluids, such as methanol, from the tubes within the umbilical.

**Regional trends in steel-tubed umbilicals**

For the steel-tubed umbilical market in particular, increased demand for natural gas due to growing electricity needs in Asia and Europe, whether due to rapidly growing economies such as China and India, economies transitioning to a post nuclear power supply or those attempting to diversify away from less secure supply sources, will increase demand for steel-tubed umbilicals over the long term.

Demand for steel-tube umbilicals, after recent peaks in 2004 and 2010, are projected to steadily grow starting in 2012 with dramatic growth materializing from 2013-15. Towards 2020, global steel-tube demand is expected to surpass 3,000 km per year, representing a material 150 percent increase on the peaks of 2004 and 2010 (Figure 16).

**Asia Pacific should have more demand for umbilicals**

The US Gulf of Mexico market, which has traditionally been one of the strongest for steel-tube umbilicals, is expected to remain relatively flat over the next two to three years as the effects of the drilling moratorium and permit slowdown coupled with the rise of onshore shale gas causes umbilical heavy long gas tiebacks to be limited. The upside, however, is that projections for accelerated demand in line with normal activity levels are expected in 2014.

Areas such as West Africa are expected to see increased volumes of primarily steel-tubed umbilicals ordered both in traditional provinces such as Angola and Nigeria as well as frontier areas such as the Transform Margin and East Africa. Offshore developments in these provinces should cause a double-digit increase in steel-tubed umbilical orders. Activity in the Mediterranean is expected to be centered on Egypt, Israel and Cyprus, and will utilize floating hosts to tie back offshore gas fields, often in tandem with subsea-to-beach schemes, with both utilizing onshore LNG plants for distribution and export.

These types of projects are vital to the umbilical market because both feature extremely long lengths and subsequently large volumes of product.
Section 1: Demand boom in subsea market

Australia, where the primary resource base consists of natural gas, continues to be one of the most important areas worldwide for steel-tube umbilicals. Subsea-to-beach developments, where natural gas is produced subsea and then brought to shore for processing into LNG, provide very high volumes of umbilical demand centered around major projects. While tube counts in these projects are relatively lower and piggyback lines are often used for flow assurance, as in the Gorgon project, the massive lengths of the umbilicals associated with these projects still drive large steel-tube orders. While subsea-to-beach projects should continue to provide significant steel-tube demand, the emergence of floating LNG technology could hinder growth in this market by taking the LNG conversion process offshore.

Regional trends in thermoplastic umbilicals

While the South American market, driven by Brazil, is poised to see the most growth in subsea tree, floating production and umbilical awards, Petrobras’ affinity for thermoplastic hosed umbilicals will result in most of this growth being met without utilizing steel tubes. Brazil will continue to be the most important market for thermoplastic umbilicals, continuing to account for the majority of demand as well as being the driver for any significant demand growth (Figure 17).

Dedicated local manufacturing coupled with many long years of design and service experience allow Petrobras to utilize specialized high-collapse-resistant (HCR) thermoplastic umbilicals at very deep water depths (including on upcoming pre-salt projects) that will likely not be replicated outside Brazil. Beyond the relatively benign conditions seen off Brazil, Petrobras’ large fleet of installation vessels coupled with their tendency to stockpile equipment should allow the company to replace a damaged umbilical and restore production in a time frame that could not be replicated elsewhere.

Thermoplastic umbilicals, which are the main competing technology for steel-tube subsea production umbilicals, are expected to see notable growth through 2020, albeit from a much smaller base than their steel-tube counterparts. While shallow-water provinces such as the North Sea and parts of Asia will provide some demand for this type of equipment, the continuing
Section 1: Demand boom in subsea market

march into ever deeper water depths will significantly hinder their ability to compete with steel-tubed umbilicals due to thermoplastic-tube technical limitations and operator preference.

Subsea market evolution

Deepwater oil and gas production is expected to nearly double to more than 18m BOE/day in 2020 compared with 9.5m BOE/day in 2010 (7% Cagr versus expected increase in worldwide total oil and gas production of 1.5%). This increase in deepwater production is aided by the tremendous growth in oil and gas industry capital expenditures worldwide for seismic, drilling, facilities and SURF (Subsea, Umbilicals, Risers and Flowlines). Quest projects global deepwater capital expenditures to exceed US$160bn in 2015, reflecting approximately 10% annual growth in the next five years, and for spending on deepwater development to become a larger portion of total worldwide upstream spending (Figure 18).

The subsea industry has evolved from a modest base, growing from several hundred subsea Christmas trees during the 1980s to more than 3,425 subsea trees from 2000 to 2009. From the first subsea tree that began producing in 1961 in 17 meters of water tying back to a fixed platform, the industry has aggressively advanced its capabilities. Subsea equipment now produces in over 3,000 meters of water and ties back production over hundreds of kilometers to shore. As such, subsea technology is opening up harsh and remote locations to hydrocarbon production, which will translate to additional global energy supply.

Subsea technology transfer - history

The great accomplishments through the history of subsea have the laid the groundwork for future success. Much like the 1980s, the essential building blocks of subsea remain reliability and quality at the most economic cost. Projected annual capital spending on subsea system start-ups is expected to grow significantly to over US$18bn in 2015. Comparatively, subsea system spending was close to US$750m per year in the 1990s and US$7.5bn per year in the late 2000s (Figure 19).
Section 1: Demand boom in subsea market

Figure 19

Global subsea production capex spend by region

<table>
<thead>
<tr>
<th>($MM)</th>
<th>25,000</th>
<th>20,000</th>
<th>15,000</th>
<th>10,000</th>
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<td>Asia Pacific/Middle East</td>
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<td>2008</td>
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</tr>
<tr>
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<td>2007</td>
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<td>2010</td>
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Source: Quest Offshore Resources, Inc

Further step changes in subsea technology over the next 20-30 years

While initially there was industry resistance to subsea production technology, it is now a widely accepted and embraced field development solution. For subsea production technology to continue to advance, engineers, research managers and regulators must continue to accept new technologies outside their comfort zones.

The subsea industry as we see it today is the result of many long years of technology advancements and the relentless pursuit of perfection. The main five suppliers for subsea hardware, led by FMC Technologies, Cameron, GE Oil & Gas, Aker Solutions and finally Dril-Quip, have continued to advance their highly engineered products over time, culminating in exceptionally reliable solutions for subsea oil and gas field developments globally. These companies will be among those who lead the industry into the next era of subsea technology, taking production equipment, boosting technology and gas compression to the sea floor.

The adoption of new subsea technologies has progressed at differing rates for major subsea oil and gas operators. However, the continued expansion into deepwater, which is driving exponential growth in subsea activity, has seen certain technologies, which were for so long considered the technologies of the future, start to become the technologies of the present.

These technologies fall into different categories, but they all share the same goals: enabling new projects, sustaining the economic life of existing projects and reducing capital and operational expenditures of offshore field development projects.

Market leaders leveraging share to compete for new boosting equipment

Subsea technology evolution

Since the dawn of subsea, it is fortunate that many field development applications have been chosen as much for their future potential as for their cost effectiveness in the current application.
Technology developed during the 1970’s pilot tests in the US Gulf of Mexico (GoM) demonstrated early on all the technology required to install, operate and maintain a remote deepwater production system throughout the field life-cycle from drilling to abandonment. In fact, this technology transfer enabled successful subsea development of the Central Comorant and Snorre fields in the North Sea, representing three generations of technology evolution over ~20 years.

Furthermore, in the early-to-mid 1990s, subsea manifolds were deployed in Brazil to accommodate large multi-well developments as well as reduce the number of risers. Moreover, there was talk of new technologies for subsea boosting, multi-phase flow and metering.

The material growth of subsea technology has been exponential since its onset in the early 1960s. The first major increase in subsea tree volume was seen in the late 1990s/early 2000s, when we also saw a leap in water-depth records to 2,245 feet from a record of 545 feet in the previous decade. By the end of 1999, the industry had installed just under 1,600 subsea trees compared just over 500 trees the previous decade. Ten years later by the end of 2009, over 3,000 subsea trees were installed. Moving towards the end of this decade, Quest projects that another 5,000 trees will come onstream, surpassing activity levels from the previous 47 years combined (Figure 20).

Once the industry realized the first giant step into deeper waters in the late 1990s, the industry was forever changed. Subsequently, the quest for the exploration of the deep and ultra-deep has continued to set new records. By the end of the 2000s the industry nearly quadrupled the water-depth record to 9,356 feet with the installation of Shell’s Silvertip tieback to their Perdido project (2008) in the GoM. At the end of 2011, Shell and FMC broke this record with a subsea tree installation in 9,627 feet of water on their Tobago field, which also ties back to Perdido. In the coming years Quest projects that the water-depth record will be pushed even further, closing in on 10,000 feet. This movement into ultra-deep waters will be felt throughout the supply chain as more technologically advanced equipment is required to overcome...
increasingly hostile environments. This need for increased technology is coupled with increased complexity and will inevitably magnify the capital spent on these projects as the supply chain expands its goods and services to meet rising demand.

To date, seven major oil companies make up slightly more than 50% of the global installed base of subsea trees. This demand is led primarily by Petrobras, which is no real surprise given the dominance of Brazil compared to the rest of the world. Total and Chevron have been and are expected to be very active as well given their presence off West Africa and the large volumes of subsea trees utilized in that region. Statoil is heavily active in the North Sea using innovative subsea technologies and is increasing its future activities pioneering enabling technologies, especially in the arena of subsea processing.

**Regional subsea analysis**

To put subsea activity in perspective, it is important to note the regions that have contributed the most growth to the overall installed base of subsea trees. The North Sea has probably been the most consistent area of demand for subsea technology since the 1970s. In addition to the demand for conventional technology, the North Sea is a proving ground for new technology deployment. Key players including those central to this study frequently use subsea technology as a standard development tool and are typically pioneers in collaboration with subsea OEMs for the advancement of new technologies.

The future of North America, namely the US Gulf of Mexico, is undergoing a current period of transition as the region conforms to new regulations. However, near-term prospects for growth have been severely stunted. The Asia Pacific region has the greatest potential for overall growth in subsea demand. Previously stranded large gas fields off Australia are now beginning to gain speed towards project sanction. In addition, we expect deepwater China, Malaysia and Indonesia to provide a significant portion of demand within the overall regional forecast.

**Figure 21**

**Global subsea tree orders**

(No. of subsea trees (Mean Case)

<table>
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<th></th>
<th>Africa/Medit.</th>
<th>Asia/Pacific</th>
<th>N. Sea</th>
<th>N. America</th>
<th>S. America</th>
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</table>

*Mean case forecast used for number of subsea tree awards
Source: Quest Offshore Resources, Inc
Section 1: Demand boom in subsea market

North Sea

The North Sea is expected to maintain its status as the most sustainable region for stable subsea tree demand (Figure 22). The region weathered the economic downturn with minimal reduction in activity and has quickly recovered in the first three quarters of 2011 towards normalcy. The North Sea benefits from a number of factors. It is dominated by aggressive oil companies like Statoil that have been executing fast-track subsea projects, mostly being awarded to FMC Technologies, in the past 12-18 months. Due to the maturity of the area, there are many opportunities for infill subsea tree awards; these comprised over 25% of the subsea tree orders in the region since 2009. The strong backlog of exploration discoveries in new and mature areas, which have yet to be developed, drives the robust outlook for projects for the region.

Figure 22

North Sea subsea tree award forecast

![Chart showing North Sea subsea tree award forecast](chart.png)

Source: Quest Offshore Resources, Inc

Statoil has fast-tracked subsea technologies because of maturity of North Sea

Flat demand for trees in North Sea

Africa and Brazil offshore fields will lead to demand for subsea equipment

Africa and Brazil represent 59% of forecast tree awards

The largest growth areas for applications of the latest subsea technology throughout this decade are easily identified as Africa and Brazil. With the high-volume tree count common to the typical projects of both areas, radical growth for both regions is assured (Figure 23).

Figure 23

Global subsea tree award forecast by hemisphere (2011-15)

![Chart showing global subsea tree award forecast by hemisphere](chart2.png)

Source: Quest Offshore Resources, Inc
Regional “hot spots” of huge reserve potential provide a substantial future demand base for goods and services related to the deepwater subsea market. Africa is projected to garner more than 20% of global demand from 2012-15 and is currently the most dynamic regional player in undeveloped potential and the translation of that into demand (Figure 24). West Africa is an established area known for “mega” deepwater developments including extensive project scopes and large capital expenditures with notable subsea project hardware tenders exceeding US$1bn. Countries in the north, south and east of the continent are supporting future demand growth through significant exploration success. The whole area is a magnet for international and independent oil companies alike, and despite ongoing geopolitical issues, will rely on ever evolving subsea technology to reach their production potential.

Figure 24

Africa/Med – Number of subsea developments by subsea tree volume

Source: Quest Offshore Resources, Inc

Brazil

Brazil’s prolific offshore market is the 800-pound gorilla in the subsea industry on the heels of their continued pre-salt discoveries. The anticipated level of long-term subsea tree demand for the area is expected to mirror numbers that historically represented global demand – a significant milestone (Figure 25).

Figure 25

Brazil’s subsea tree demand versus rest of world

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</table>

Source: Quest Offshore Resources, Inc
Petrobras is aggressively pursuing the development of their lucrative pre-salt developments in concert with the dedicated development of their longstanding, tremendously successful subsea developments in the post-salt. Due to reservoir characteristics, traditional deepwater developments off Brazil require high volumes (15+) of subsea trees (Figure 27) with associated Floating Production Storage and Offloading (FPSO). Due to their higher energy, pre-salt reservoirs are expected to require fewer subsea trees per project. The reserves, however, are massive enough that each discovery will require numerous phases to fully exploit. Moreover, this region represents huge potential for advanced applications of subsea processing, namely subsea boosting and subsea separation. Petrobras currently has its Marlim subsea separation pilot on its way to being delivered from FMC Technologies, which will provide insight into the future of that application for Petrobras.

**Figure 26**

**Marlim field layout in Brazil**

![Marlim field layout in Brazil](source: FMC Technologies)

**Figure 27**

**Brazil subsea tree awards by project size**

<table>
<thead>
<tr>
<th>Year</th>
<th>1-2 Trees</th>
<th>6-10 Trees</th>
<th>11-25 Trees</th>
<th>26+ Trees</th>
<th>Projects (RHS)</th>
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<td>2015</td>
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</table>

Source: Quest Offshore Resources, Inc
Asia Pacific

Asia remains a smaller piece of the overall pie, but the potential of the area cannot be overlooked. Coming from such a small installed base of subsea trees, we see the growth potential in the area to be second only to Africa over the next 15-plus years (Figure 28).

Asia Pacific subsea tree award forecast

<table>
<thead>
<tr>
<th>Award Year</th>
<th>No. of subsea tree awards</th>
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</thead>
<tbody>
<tr>
<td>2003-2005</td>
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<td>2006-2008</td>
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<td>2009-2011</td>
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<td>2012-2014e</td>
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</table>

Source: Quest Offshore Resources, Inc

Asia Pacific is experiencing a step-change in subsea activity with a more than doubling of subsea awards over the next three years driven by long-offset, stranded mega gas projects that are moving quickly towards sanction. LNG has become an enabling technology for projects that have been in backlog for at least five years. Land-based LNG will be the main mode of development for gas projects offshore northwest Australia, but the innovative floating LNG solution pioneered by Shell and contractor Technip will be utilized for the first time on the Prelude project. Quest anticipates this momentum to continue well into the next decade offshore Australia. Despite the resource potential of these finds, the subsea tree demand is disproportionately low when compared to what we would expect from other mega-projects around the world. Some of the hidden value in these long subsea-tieback projects comes from the volume of subsea production umbilicals and pipelines tying these remote fields back to onshore production facilities. Other areas within Asia Pacific contributing to subsea demand include deepwater China, Malaysia and Indonesia. The inconsistency of project executions historically in this region has led to the lumpiness we commonly see in overall activity trends, but the long-term potential for continued, material demand is secure and projected to be long lasting.

North America

Just as industry drivers were moving in a positive direction, there was the Macondo oil spill in the US Gulf of Mexico in 2010 which dramatically affected project execution (Figure 29). Oil companies had to re-evaluate and analyze how they approached drilling operations, well operations and safety cases and procedures in order to do their best to prevent another oil spill. There was a short-term halt of all deepwater drilling, followed by a transition period into new regulations and requirements lengthening the time it takes oil companies to get permits to drill. Moreover, emergency subsea oil containment solutions have been engineered and delivered to the market place. Whether the longer time-frame to get drilling permits is permanent or not, the current situation will impact award activity in the area will see over the next 12-24 months and more notably US production levels over the next three to four years.
Section 1: Demand boom in subsea market

Even with these factors limiting subsea order growth in the GoM, there were a number of mega-projects in the US Gulf of Mexico that were able to move ahead to sanction because project execution was not contingent on further appraisal drilling to prove commerciality. These projects include Chevron’s world-class Jack/St Malo, Shell’s Mars B, Anadarko’s Lucius and ExxonMobil’s Hadrian projects. A number of the developments currently being executed in the Macondo aftermath included dry-tree solutions on floating production systems. While this trend is positive in terms of current capital expenditure in the area, the subsea market is presently at its lowest point in recent history, with a low level of subsea tiebacks on average ranging from three to 13 per year during 2010-12 (Figure 29). The US Gulf of Mexico, much like the UK sector of the North Sea, requires an environment conducive for small independents to quickly and efficiently develop their offshore finds. To this end, the US Gulf of Mexico’s operating environment will need to stabilize considerably before normal activity levels resume.

Tiebacks versus stand-alone developments

The global subsea industry saw a marked recovery in the number of subsea tiebacks and floating production-system (FPS) stand-alone developments executed in 2011, up over 60% year over year; there were 48 projects in 2010 versus 80 projects in 2011 (Figure 30). This was driven by a significant increase in subsea tiebacks executed in the North Sea (29 subsea tieback projects in 2011 compared to nine in 2010). This is a promising trend as it indicates that independent operators, who usually operate subsea tiebacks, are continuing to develop these.

Statoil also aggressively executed a number of “fast track” subsea tiebacks during 2011, with a goal to increase production over the next 24 months. As subsea tiebacks tend to develop marginal reserves, and are less capital-intensive than large stand-alone developments that target larger reserves at higher costs, there are far more project opportunities for subsea tiebacks overall than stand-alone developments. This increase in subsea tiebacks also bodes well for the oilfield service companies because a larger volume of projects lends itself to a larger opportunity base for associated goods and services contracts.
Section 1: Demand boom in subsea market

Tree awards dropped in 2011, even though tiebacks and dry tree floating production-system installations increased worldwide.

Vessels that store production from offshore wells increase potential for subsea infill orders.

Offshore storage units should reduce the cost of developing ancillary fields with subsea trees.

The industry also had a significant increase in FPS stand-alone developments in 2011, which are expected to lead an up-cycle in future years for developing ancillary fields with subsea trees (Figure 31). Although these developments represent fewer overall opportunities for the supply community, they do represent significant capital investment from the exploration phase through to start-up – some mega projects are running as high as US$10bn in total.

The US Gulf of Mexico experienced a resurgence of FPS activity in 2011 with four hull awards (Chevron’s Jack/St Malo, Anadarko Petroleum’s Lucius, Chevron’s Big Foot, Hess’ Tubular Bells) – the highest level of awards in the region since 2006. OGX and Petrobras offshore Brazil are expected to lead 2011 FPS stand-alone demand with 13 FPSO awards. The projected 21% 2011-15 compound annual growth is driven primarily by Brazil’s increased demand for FPSOs and FPS-semi submersibles (Figure 31). Africa and Asia, historically the cornerstones for FPS demand, are expected to continue to drive large growth rates for FPSO units, both newbuilds and conversions.

Figure 30
Global subsea tiebacks versus stand-alone developments

Source: Quest Offshore Resources, Inc

Figure 31
Global FPS hull awards by type

Source: Quest Offshore Resources, Inc
Section 2: Frontier expansion with subsea equipment

Frontier expansion with subsea equipment

Subsea 101

In deepwater environments, the application of a fixed platform is unfeasible; the practical limit is 1,000 feet. Therefore, in deep water, operators must use floating hosts or a floating production system (FPS). The FPS solutions that are currently available are the Tension-Leg Platform (TLP), the SPAR, the Semi-Submersible platform, and in specific instances a Floating Production Storage and Offloading (FPSO) and monobuoy vessel.

Tension-Leg Platforms are very buoyant platforms either with three or four columns that are moored to the sea bottom via multiple steel tendons. These tendons are shorter than the distance the platform would settle at if it was not moored to the sea floor; this keeps the platform very stable and prevents vertical and horizontal movement thus allowing drilling operations to be conducted from the platform.

Spar platforms are long cylindrical hulled platforms with the length and weight of the hull, providing the stability necessary to conduct drilling operations. Due to the length of the hull, the hull must be towed out to the field horizontally and righted at the field. Therefore, topsides must be lifted and integrated onto the platform offshore.

Semi-submersible platforms, which are often utilized for the largest projects in the offshore Gulf of Mexico normally, consist of four columns on pontoons with a large deck built on top. The arrangement leads to a large topside area. The lower part of the hull sits below the water level while the upper part sits above the waterline; this can be actively adjusted via the movement of water into and out of the ballast tanks that are inside the pontoons at the bottom of the hull.

Floating production storage and offloading units (FPSOs) is a technology that is rare in the Gulf, with only one existing unit which is due to start up this year in the USA and one unit active off Mexico. These are of a simpler design, which basically constitutes a strengthened oil tanker (VLCC) with production topsides. This allows for the export of oil without a pipeline and thus makes it more common in less developed regions where less infrastructure is in place.

Most floating production unit fabrication is done in Asia, with yards also in the USA, Brazil, Middle East and North Sea participating in this market.

Deepwater fields: SURF equipment

Equipment below the water line and at the sea floor is generally referred to as the “SURF” market, where SURF stands for Subsea, Umbilicals, Risers and Flowlines. These technologically advanced components tie together to power and transport the production back to the surface facility for processing and delivery. A thorough review of each of these components is provided below.

Subsea equipment

While subsea equipment is used as a “catch all” for a large portion of the equipment on the sea floor, the most critical component of subsea production equipment is the subsea “Christmas tree,” or tree and control system. The tree and control pod is a highly technical piece of equipment that sits on top of the well and allows for the control of each well’s production and performance.
These pieces of equipment are of a fairly standard composition from a general standpoint, but differ greatly from oilfield to oilfield. However, all trees serve as the primary access point to the reservoir(s) being produced on a field (non-surface applications). Operating oil companies often access a well via the subsea tree to perform operating maintenance operations to ensure a safe and productive flow of liquids from the well.

**Subsea tree**

The subsea tree is a permanent structure deployed on the seabed on top of the wellhead to control and monitor production. On average a subsea tree weighs between 30-60 tonnes depending on complexity of the tree (gas trees are generally bigger than oil trees due to larger boreholes necessary for the flow). Trees are typically 5-10 meters tall.

The tree controls the injection of fluids and chemicals, and also allows access for well intervention. The subsea tree is normally controlled hydraulically via a subsea control module to actuate valves to inject fluids and chemicals. However, in Brazil for Petrobras for their standard, non-pre-salt subsea trees, they directly control these trees from the topsides of the production host. Horizontal versus vertical subsea tree types refer to the orientation of valves on the tree.

The subsea tree attaches to the wellhead, then the tree attaches to an umbilical via a flying lead. A jumper connects the well and subsea tree (usually via a pipeline end termination) to a pipeline, which then connects to the manifold.

While onshore trees are normally multiple flanged sections for attaching to another object, subsea trees are normally fashioned from a solid piece of metal with valves attached due to the pressure encountered on the seabed.

**Other subsea components**

Other components included in the broader “subsea” equipment category include the various pieces of connection machinery.

These include:

- Subsea control system: series of controls that attach to the subsea tree for means of controlling the safety valves and controls the flow from the subsea tree
- Manifold: A central collection point for multiple subsea wells. A manifold is then connected to a pipeline to transport production to the host location
- Pipeline end termination (PLET): a connection point between a pipeline and a subsea tree or manifold
- Jumper: short, pipeline-like link connecting a PLET or manifold to a pipeline
- Flying lead: short-range connector of power (electric or hydraulic) to subsea tree(s)

Whatever the specific component, the pieces of equipment in the “Subsea” category of SURF all serve to connect and control production from the well to the infrastructure and equipment that will transport the produced product.
Umbilicals
The umbilical performs functions that are required to provide power and fluids to the entire subsea production system. These “cables” are often very complex and technologically advanced and contain multiple functions in a single umbilical.

Moreover, in addition to providing the electrical or hydraulic power for the subsea trees, these cables also carry various chemicals that are injected into a well to enhance production and inhibit the formation of hydrates that can block the flow of liquids through the well. This optimization process is called flow assurance.

The umbilicals often require a large amount of engineering to ensure there is no negative interaction between the power and other functions in a single umbilical. Additionally, as umbilicals increase in the number of functions contained in a single line, the installation of that line becomes increasingly difficult, requiring extensive installation engineering to ensure that the unit is not damaged during installation and before coming online. These installation operations also require specialized and expensive marine construction and installation equipment.

Risers & flowlines
The “R” (risers) and “F” (flowlines) portions of the SURF market refer to the pipelines needed for any offshore oilfield (the term flowlines is used interchangeably with pipelines). Both segments refer to the pipeline transportation system of an oilfield.

The risers are pipelines that are run vertically to connect the production facility at the surface with the subsea hardware and equipment on the sea floor. While at first glance the riser pipelines may seem fairly rudimentary in terms of technology, these pieces of equipment are actually very highly engineered. Since risers run through the entire depth of the water column, these lines are subject to a great deal of environmental conditions with the potential to create disarray on any offshore oil-production project.

Additionally, risers are still evolving as oil companies and equipment providers strive to refine and perfect these technologies. A few added benefits of increasingly new riser technologies will be the ability to quickly disconnect a surface facility in the event of a hurricane, reduce the weight of the riser to allow for smaller facilities, and many other technological advances that will increase the efficiency by which produced liquids flow through the pipeline system. Pipelines are used to transport material both to and from a producing well(s). As with risers, the primary purpose of an offshore, subsea flowline is to transport liquids either from the well back to the host facility or from the host facility back to shore.

While conceptually fairly straightforward, the risers and flowlines of an oilfield are some of the most critical components and they employ a high degree of technical complexity and subsequently high capital cost. To install offshore risers and flowlines, the offshore oil and natural-gas industry utilizes a fleet of specialized offshore installation boats.

These boats, or “vessels,” are large and expensive pieces of equipment, ranging from US$150m to more than US$1bn to design and build. For this reason, installation contractors are very selective when deciding whether or not to build any new vessels.
Deepwater exploration background

The need to find and replace large pockets of oil reserves has become a driving force in the current deepwater exploration drilling upcycle. This secular trend of more exploration in deeper waters will increase demand for subsea equipment. Most of the world’s proven oil reserves are currently in or past peak production while energy demand continues to increase, resulting in a need to find new sources. In contrast to near-shore exploration which is typically gas driven, deepwater areas far from shore contain large quantities of heavy and light crude essential to global energy needs.

The investments needed to explore and appraise in deep water are much higher than traditional shallow or onshore drilling, but with oil prices expected to continue upward over coming years, more operators are able to justify the risk and capital needed to explore in the deepwater. Approximately 70% of deepwater exploration is conducted by operators with the deepest pockets, led by supermajors Shell, Total, Chevron, Eni and BP. National oil companies including Petrobras, Statoil, CNOOC, Petronas and ONGC have expanded deepwater exploration programs recently in and out of their boundaries while Pemex has begun to move into deeper waters off Mexico (Figure 32). A handful of independent oil companies are considered leaders in deepwater exploration activity including Anadarko Petroleum, Hess, BHP, Murphy Oil, Noble Energy and Tullow Oil.

As of January 2012, 144 floating rigs are operating in waters >1,500 feet. The largest market for deep and ultra-deepwater exploration is found in the areas dubbed the Golden Triangle which consists of US Gulf of Mexico, Brazil and West Africa. Over 70% of all offshore drilling – whether shallow or deepwater – from floating rigs occurs in these three areas (Figure 33). That percentage jumps to 80% in water depths over 4,000 feet.

Source: Quest Offshore Resources, Inc. Notes: AFM=Africa/Mediterranean, ASP=Asia Pacific, NAM=North America, NSEA = North Sea, SAM=South America; 786 prospects
Brazil deepwater exploration
Brazilian oil deposits contained below layers of thick salt are thought to hold 50-120bn barrels of reserves, which even at the low end of that estimate is higher than the 31bn barrels of proved oil reserves in the USA in 2011, according to BP. In 2006 the first discovery well was drilled at Tupi in block BM-S-11 and in 2010 Brazilian authorities passed a bill making Petrobras the operator of all new pre-salt exploration licenses.

Petrobras currently has over 16bn barrels of proven reserves, and the company is investing over US$200bn in five years to explore and begin early production wells in the pre-salt area. The operator has over 60 floating rigs in operation off Brazil, which is more than any one operator has globally.

Gulf of Mexico deepwater exploration
The deepwater Gulf of Mexico remains a viable component to the Golden Triangle despite the slowdown in 2010-11 post Macondo. Exploration activity is now focused on the Lower Tertiary areas of the Gulf which is estimated to hold up to 15bn barrels of recoverable reserves. The wells being drilled in the lower tertiary are extremely challenging. Recovery rates are typically less than 30% and it could take upwards of ten years from first discovery to first oil, requiring an investment in the multi-billions. There have been less than 30 discoveries in the lower tertiary, with the most notable being Shell’s Perdido, Chevron’s Jack/St Malo, Petrobras’ Cascade-Chinook, BP’s Kaskida and Tiber and ExxonMobil’s Hadrian North and South (Figure 34).

West Africa deepwater exploration
The third prolific area of the Golden Triangle is West Africa. Operators including Shell, Total, Chevron, ExxonMobil and BP have experienced very successful deepwater exploration off the coasts of Nigeria since the 1970s and
Angola since the 1990s. Exploration is also widely dispersed along other West African countries such as Cameroon, Equatorial Guinea, and Gabon. In recent years a new geographic trend has emerged called the Transform Margin, an area that stretches 1,500km along Ghana, across the Ivory Coast and Liberia and to the west of Sierra Leone. The area was first discovered in 2007 by Kosmos Energy in the Jubilee field off Ghana. It only took 42 months from discovery to first oil and the Jubilee Phase One development is now producing 120,000 bopd.

Several floating rigs have been mobilized to the Transform Margin and an active exploration campaign is planned over the next several years from operators such as Anadarko, Vanco, Hess, Chevron, Eni and Lukoil. The simplicity of the play elements off West Africa makes this area different from the high-cost Brazil pre-salt or the challenging reservoir conditions of the Gulf of Mexico’s lower tertiary. Common characteristics for Africa include: an abundance of rich oil-prone source rocks, thick clean sands and young structures at more shallow depths.

North Sea deepwater exploration
The most mature area for offshore deepwater exploration is the North Sea. Over the past decade, exploration drilling off the Norway and the UK have been relatively flat but sustained, buoyed by high oil prices, the need to maintain production capacity at high cost and strategic fixed-platform and floating hubs. Thanks to technology advancement in rig designs and recent drilling success, operators have begun to move into harsher environments such as the Barents Sea and West of Shetlands where very little drilling has taken place. In 2011, both Statoil and Lundin Petroleum announced major offshore finds off Norway that are some of the largest in history for the region.

Asia Pacific deepwater exploration
Parts of the Asia Pacific region are expected to grow by large percentages over the next several years led by increased spending by CNOOC in Bohai Bay off China, Petronas off Malaysia and Inpex off Australia. Other areas of notable interest for deepwater exploration include Indonesia, Vietnam and India (Figure 35).

There are 82 near-term deepwater prospects in Asia Pacific
Australia, China and New Zealand have the largest portion of prospects in Asia Pacific

Asia Pacific deepwater (>1,500 feet) exploration by province 2012-14

Source: Quest Offshore Resources, Inc; 82 prospects
Emerging frontier areas for exploration

Beyond the activity in the Golden Triangle a new wave of deepwater exploration activity is emerging in new frontier areas including:

- East Africa (Mozambique, Tanzania, Kenya, Madagascar)
- West Africa (Liberia, Sierra Leone, Cote D’Ivoire)
- Eastern Mediterranean (Israel, Cyprus)
- Arctic (Greenland, Barents, West Shetlands, Alaska)
- Eastern Europe/Russia (Black Sea, Caspian)
- Northern South America (Falklands, French Guiana, Suriname)
- Mexico Deepwater (Mexican Gulf of Mexico)
- China Deepwater (Bohai Bay)
- Cuba

Operators face new challenges when entering frontier plays such as more extreme environments, new governments and regulatory issues, lack of infrastructure, availability of rigs and limited availability of skilled indigenous workforce. Over 60 operators have made new investments in frontier areas in just the past few years and have started exploration drilling or plan to begin in the near-term horizon (1-3 years). The group includes seven super-majors, thirty-seven independent oil companies and seventeen national oil companies (Figure 36). Quest has identified 289 frontier exploration prospects drilled and undrilled of which roughly 60% are in waters <=4,000 feet and 40% in water >4,000 feet. Currently, there are 33 floating rigs operating in deepwater frontier areas of the world, 13% of the total rigs operating at January 2012. The twenty-two entities operating these 33 rigs include five supermajors, nine independent oil companies and eight national oil companies (Figure 36).
Section 2: Frontier expansion with subsea equipment

Among 289 exploration prospects identified in offshore frontier regions, 46% have been drilled since 2008 and 54% are expected to spud over the next 3-5 years.

<table>
<thead>
<tr>
<th>Figure 37</th>
<th>Offshore frontier exploration prospects drilled and undrilled 2009-14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Super-Majors 18%</td>
</tr>
<tr>
<td></td>
<td>Nationals 28%</td>
</tr>
<tr>
<td></td>
<td>Independents 54%</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc; 289 wells

Quest is tracking 2,340 offshore exploration prospects worldwide in the same timeframe of 2009-14 (821 in waters >4,000 feet), among which 971 have been drilled in the past three years (310 in water >4,000 feet).

Deepwater exploration is challenging

Twenty-six years later, the comments of Exxon Company's Harry J. Longwell at an Offshore Technology Conference on 6 May 1985 still ring true today with respect to the material challenges of deepwater:

As you know, the history of the offshore industry is a story of competitive challenge in competition for leases and reserves among products and systems, between individuals and organizations, and for investment dollars. But there is yet another form of competition that looms large on our horizon. It is the "deep" in deep water, and it puts a distance between us and a most promising resource frontier. It is our challenge, then, to marshal and develop the competitive technologies necessary to span this distance in such a manner as to achieve economic development of these opportunities.

It is now obvious that all of our production concepts benefit from the successes of one, through the twin spin-offs of innovation with creativity and enterprise with competition when these spin-off forces are at work in the proper environment they tend to create both a larger demand for and a greater supply of high quality technology and thus, opportunity . . ."

Source: Quest Offshore Resources, Inc

Deepwater drilling

New contracts for deepwater rigs are a leading indicator for future demand for subsea equipment. There are 277 floating drilling rigs in the current global fleet. Quest forecasts that number will increase 26% by 2015 to about 350 floating rigs in global supply (excludes attrition) (Figure 39). Contracted utilization for floating rigs overall is nearly 90% while only 33 rigs are currently stacked. The profile of the existing fleet has gone through changes over the past decade with the expansion of ultra-deepwater rigs into the supply (rigs rated to work in water depths >=7,500 feet).

At the end of 2001 ultra-deepwater rigs only made up 15% of the global supply. Today, ultra-deepwater rigs make up 41% of the global supply and by the end of 2015 half of the entire global fleet will be made up of ultra-deepwater rigs. The primary driver behind heightened demand for these new generation rigs is the increase in well demand within the Golden Triangle regions where the majority of deepwater oil reserves are yet to be tapped. There are currently 115 ultra-deepwater floating rigs operating in the Golden Triangle (Figure 40).

The discovery of pre-salt offshore Brazil has created greater new demand for ultra-deepwater rigs than any other region. In 2009 Petrobras announced plans to build 28 new rigs in Brazil for delivery starting in 2015, of which seven have been awarded for construction. The US GoM remains a very active...
Section 2: Frontier expansion with subsea equipment

Tighter rocks, higher pressures, higher temperatures and remote locations require modern rigs

region for deployment of ultra-deep rigs. Despite the permitting slowdown post the moratorium, nine new ultra-deepwater rigs were delivered to the Gulf of Mexico from 2010-11 and seven additional units have been ordered for delivery to the region from 2012-14. Successful oil exploration campaigns followed by large-scale development programs off West Africa, and more recently East Africa, has led to increasing demand for ultra-deepwater rigs year over year.

Another factor for the rise in newbuild high-spec ultra-deepwater rigs is the preference among operators for enhanced capabilities, greater efficiencies and better safety profiles as they move into reservoirs with tighter rock, higher pressures and temperatures and in remote locations. The modern ultra-deepwater rig offers features such as retractable thrusters, dual-activity capability, increased hook-load capacity, a seven-ram BOP with a fully acoustic back-up control system, accommodation for a second BOP, an active heavy- crane system that allows for simultaneous deployment of subsea equipment and variable deck-loads up to 20,000 tons. Construction costs can range from US$600-700m and average day-rates tend to run in the mid US$500,000 region.

Offshore drillers likely to continue building new rigs to meet secular growth in demand for deepwater rigs

Ultra-deepwater rigs: rigs rated to work in water depths greater than or equal to 7,500 feet

Figure 39
Floating rig global fleet 2008-14

<table>
<thead>
<tr>
<th>Rig Count</th>
<th>Year In-Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>190</td>
<td>2008</td>
</tr>
<tr>
<td>210</td>
<td>2009</td>
</tr>
<tr>
<td>230</td>
<td>2010</td>
</tr>
<tr>
<td>250</td>
<td>2011</td>
</tr>
<tr>
<td>270</td>
<td>2012</td>
</tr>
<tr>
<td>290</td>
<td>2013</td>
</tr>
<tr>
<td>310</td>
<td>2014</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

Figure 40
Ultra-deepwater floating rigs operating in Golden Triangle

Source: Quest Offshore Resources, Inc; 115 rigs
Section 2: Frontier expansion with subsea equipment

Growth in contracts for floaters has increased in the last decade

Figure 41

Drillships and semis with contracts an indicator of deepwater development

Source: ODS-Petrodata

We expect demand for floating rigs will absorb a 30% increase in supply

Figure 42

Utilization of floating rigs (drillships and semis)

<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>11E</th>
<th>12E</th>
<th>13E</th>
<th>14E</th>
<th>15E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floating rig supply</td>
<td>208</td>
<td>226</td>
<td>245</td>
<td>273</td>
<td>288</td>
<td>314</td>
<td>326</td>
<td>333</td>
</tr>
<tr>
<td>Floating rig contracts</td>
<td>201</td>
<td>209</td>
<td>220</td>
<td>243</td>
<td>259</td>
<td>292</td>
<td>305</td>
<td>317</td>
</tr>
</tbody>
</table>

Utilization of supply (%) | 97 | 92 | 90 | 89 | 90 | 93 | 94 | 95 |

Source: ODS-Petrodata, Credit Agricole Securities (USA) estimates

2010 was a record year for deepwater discoveries

Deepwater discoveries
Since 2004 there have been more than 1,200 discoveries announced in areas of potential for subsea development (see Figures 43 and 44). Over half of those discoveries have been in water depths greater than 1,500 feet and nearly 30% in water depths greater than 4,000 feet. Areas with greatest success in deepwater include the Golden Triangle regions while the North Sea plays a significant role in the mid-water sector where numerous subsea tiebacks are used to keep capacity full at older platforms. Since 2007 there has been growth in drilling in Asia in water depths greater than 1,500 feet. Despite a moratorium in the Gulf of Mexico, 2010 was a peak year for offshore discoveries driven by high success rates offshore Brazil and Australia (Figure 45).

South America had the most discoveries in 2010 and 2011

Figure 43

Global offshore discoveries 2004-11

Source: Quest Offshore Resources, Inc; 1,265 discoveries
The 1,265 discoveries since 2004 create a pipeline of future subsea equipment orders – depending on timeline for producing from discoveries.

### Global offshore discoveries 2004-11

<table>
<thead>
<tr>
<th>Year(s)</th>
<th>Water depth (ft)</th>
<th>Operator</th>
<th>Potential # of wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>6,500</td>
<td>BP</td>
<td>120</td>
</tr>
<tr>
<td>2005</td>
<td>4,100</td>
<td>Shell</td>
<td>95</td>
</tr>
<tr>
<td>2006</td>
<td>4,330</td>
<td>Tullow Oil</td>
<td>22</td>
</tr>
<tr>
<td>2007</td>
<td>4,800</td>
<td>Anadarko</td>
<td>45</td>
</tr>
<tr>
<td>2008</td>
<td>5,500</td>
<td>Noble Energy</td>
<td>46</td>
</tr>
<tr>
<td>2009</td>
<td>4,000</td>
<td>Husky Oil</td>
<td>61</td>
</tr>
<tr>
<td>2010</td>
<td>5,000</td>
<td>Pemex</td>
<td>15</td>
</tr>
<tr>
<td>2011</td>
<td>4,130</td>
<td>BP</td>
<td>15</td>
</tr>
<tr>
<td>2012</td>
<td>7,100</td>
<td>Chevron</td>
<td>24</td>
</tr>
<tr>
<td>2013</td>
<td>8,000</td>
<td>Shell</td>
<td>26</td>
</tr>
<tr>
<td>2014</td>
<td>6,700</td>
<td>Tullow Oil</td>
<td>15</td>
</tr>
<tr>
<td>2015</td>
<td>1,300</td>
<td>Rockhopper</td>
<td>36</td>
</tr>
<tr>
<td>2016</td>
<td>7,100</td>
<td>Petrobras</td>
<td>&gt;200</td>
</tr>
<tr>
<td>2017</td>
<td>7,000</td>
<td>Petrobras</td>
<td>80</td>
</tr>
<tr>
<td>2018</td>
<td>4,400</td>
<td>BP (Devon)</td>
<td>20</td>
</tr>
<tr>
<td>2019</td>
<td>4,900</td>
<td>Husky Oil</td>
<td>16</td>
</tr>
<tr>
<td>2020</td>
<td>700</td>
<td>Chevron</td>
<td>11</td>
</tr>
<tr>
<td>2021</td>
<td>1,000</td>
<td>Inpex</td>
<td>47</td>
</tr>
<tr>
<td>2022</td>
<td>3,280</td>
<td>Reliance</td>
<td>90</td>
</tr>
<tr>
<td>2023</td>
<td>4,400</td>
<td>Murphy Oil</td>
<td>16</td>
</tr>
<tr>
<td>2024</td>
<td>380</td>
<td>Statoil/Lundin</td>
<td>15</td>
</tr>
<tr>
<td>2025</td>
<td>1,000</td>
<td>Statoil</td>
<td>16</td>
</tr>
<tr>
<td>2026</td>
<td>1,215</td>
<td>Total</td>
<td>16</td>
</tr>
<tr>
<td>2027</td>
<td>3,660</td>
<td>Chevron</td>
<td>20</td>
</tr>
<tr>
<td>2028</td>
<td>1,640</td>
<td>ATP</td>
<td>16</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc
New technology creating subsea factories

The offshore oil and gas industry has long been a trendsetter when it comes to the development and implementation of new technologies, with many pioneering advancements over the decades. Moreover, the advent of new technology allowing the remote access of resources below the water facilitated the move to offshore oil production. New technology will continue to punctuate the industry’s continued march into deeper and deeper waters to access new oil reserves.

Major oilfield operators, as well as their suppliers, remain committed to constantly advancing subsea technology. From its earliest beginnings, subsea technology has advanced to points that were seemingly unimaginable. Large operators who have been willing to adopt new technology have been the most successful in the deepwater, as measured in record-breaking accomplishments, as well as executing projects that maximize oil production while minimizing cost and risk. Relatively new subsea technology can improve production from the ocean floor using new processing, boosting and separation equipment.

The future of subsea processing seems bright; once considered a novel technology with only limited real-world functionality, subsea processing is reaching the point where it is at least considered (if not favored) on major deepwater processing and is almost a must for economical development of large projects.

While in these new frontier regions (green fields) subsea processing is seen as an enabling technology, in a world of high oil prices and dwindling access to reserves, subsea processing is also seen as a key technology in extending the lives and production of major existing fields (brown fields). Increasing recovery factors from offshore fields through enhanced oil-recovery efforts is one of the most cost-effective methods of adding reserves to a company’s books and increasing oil production in a world where most of the peer group studied faces limited access to new oil-bearing regions.

Even subsea gas compression, the least mature of subsea processing technologies, will grow in importance as developing nations continue to demand ever increasing energy supplies and governments push to increase natural-gas consumption for environmental reasons. These factors should combine to make subsea processing applications increasingly common in the coming years.

Subsea processing components

Subsea processing equipment boosts, separates and compresses output in order to increase a well’s recovery rate to enhance project economics. This functionality moves efforts to boost a well’s production rate from a platform or floater topside onto the sea floor. Subsea processing can reduce topside weight in a new “greenfield” project and can make the space limitations of existing topside platforms in existing/“brownfield” projects irrelevant.

- Subsea boosting (including pumping)
- Subsea separation and processing (including High Integrity Pressure Protection Systems – “HIPPS”)
- Subsea gas compression

Petrobras and Statoil lead the industry in subsea processing applications

Petrobras and Statoil have been early adopters of subsea processing technology

Subsea processing equipment has been on the “wish list” of subsea engineers for over twenty years. However, this technology has only recently become a technology that can be considered mature enough to be utilized on key capital projects. While adoption rates vary greatly by operator, Petrobras and
Statoil lead other operators with over ten applications of subsea processing technology. Other major operators have shown a very keen interest in the further development and application of subsea processing technologies, as these systems can both decrease costs and increase production.

By relocating some portion of processing to the seafloor, operators are able to deploy host facilities that are smaller (due to a decreased need for topside processing capacity) and subsequently less expensive. Since floating host facilities are one of the largest capital expenses for any offshore project, this is a key economic benefit of subsea processing technologies.

**Subsea boosting commonly used**

Subsea boosting is the most commonly and widely used subsea processing application, currently accounting for 57 percent of subsea processing applications. Subsea boosting, i.e., artificial lift from the seafloor, stimulates hydrocarbons from the sea floor to the surface. The main drivers of boosting are greenfield heavy oil/low drive reservoirs and brownfield enhanced oil recovery. Subsea boosting technology has been utilized worldwide with applications in all five major deepwater hemispheres. Additionally, all the operators we studied have deployed this technology. While greenfield applications have historically dominated subsea boosting applications - with around 80 percent of applications – we project material growth in future brownfield opportunities as subsea developments mature.

Key regions for subsea boosting technology include the:

- Gulf of Mexico lower tertiary play where subsea pumping is considered to be an enabling technology due low-drive/high-reserve reservoirs
- Brazilian non-pre-salt fields for both brownfield and greenfield applications owing to their heavy oil and low gas content
- Large West African fields with similar characteristics to the GoM and Brazilian fields mentioned above, and
- Brownfield North Sea application due the large, high-cost infrastructure already in place, and maturity of fields with low recovery rates

Schlumberger-Framo is the market leader in subsea boosting with the majority of the 112 subsea pumps installed or qualified (Figure 47). FMC Technologies participates in over one-third of subsea boosting projects (Figure 46). The first application of a piece of subsea processing equipment with boosting capability was at Shell’s Draugen field in Norway.

![Global subsea boosting market share by manufacturer](image-url)
Subsea boosting-pump manufacturers
The first subsea boosting equipment used by Shell in Norway had a helico-axial pump. Today, there are more than 112 pumps currently used in subsea fields, with 40% of these pumps electrical submersible pumps (ESP), which were originally designed for down-hole applications (Figure 48). Other pump types include twin screw pumps (first deployed in 2007 by BP on the King Pump project), centrifugal pumps first deployed in 1996 by Statoil on China’s Lufeng project, and helico-axial pumps first deployed on Draugen. Despite being the most deployed with 40% of pumps, ESPs are the most technologically limited pumps; they are limited to production streams with low gas cuts and have the shortest design lives. In fact, one of the main drivers of placing ESPs on the seabed is removing them from the well bore and thus allowing easier intervention and replacement. Helico-axial and centrifugal pumps also face declining efficiencies with increasing gas cuts. Subsea pump engineering and manufacturing is the purview of companies such as Baker Hughes, Bornemann, Leistritz and Schlumberger-Framo.

Subsea separation
Subsea separation station separates water from the wellstream. This separation process often accompanies a boosting system that drives the separated gas and oil to the topside or shore, depending on the field design. A subsea raw water injection re-injects the separated water directly back into the reservoir.

FMC Technologies is the market leader in this segment, based on the eight systems installed or qualified to date (Figure 50).
The first operational subsea separation system was installed in a brownfield application at the Troll C semi-floating production facility offshore Norway. Conceived as a test system, this project introduced separation by showing its ability in brownfield applications where the existing platform was no longer able to able to continue to produce at economic levels due to increasing water cut. The subsea separation system allowed for increased production not only by decreasing water produced to the platform, but also allowing more effective pumping due to a reduction of the gas cut in the well stream.

Norway has seen other notable separation projects with the Tordis system (another brownfield application) most notable, as it is the largest separation unit currently delivered. Other notable subsea separation projects worldwide are Total's CLOV and Pazflor projects offshore Angola, which are being deployed on large new projects with separation utilized to enable more effective pumping of low-pressure oil at a greater distance from the host. In the Gulf of Mexico, Shell’s Perdido project also utilizes gas separation to improve pump performance in very deep water given a reservoir that has low drive oil.
The very heavy oil offshore Brazil has led to it being a “hot bed” for separation, with Shell applying separation coupled with boosting on the BC-10 project (Figure 51). Petrobras, meanwhile, utilized separation multiple times in their traditional non pre-salt projects such as Marlim and Marimba. Future opportunities are likely to be in similar situations with North Sea and South American brownfield applications leading the way. Lower tertiary applications such as Perdido remain possibilities; however, it is notable that the most recent developments have utilized boosting-only systems due to lower gas cuts than were found at the Perdido development.

**Subsea high-integrity pressure protection systems (HIPPS)**

Subsea high-integrity pressure protection systems (HIPPS) aim to protect subsea flowlines and risers from overpressure by shutting down production at the subsea level. HIPPS is an evolving technology often seen as a key enabling technology for deepwater subsea development. These systems have the potential to reduce both capital and operating expenditure, as well as preventing major incidents that could lead to expensive shutdowns.

Subsea HIPPS systems should continue to grow in usage, especially with the expected return to a high-cost environment for offshore operators. As HIPPS’ main cost savings are experienced in pipeline procurement, this effect could be quite pronounced as steel costs rise at rates faster than other offshore commodities, and longer tiebacks lead to more pipeline-intensive projects. The growing track record of successfully deployed HIPPS systems in more and more challenging environments should lead many operators to consider this technology despite some possible fears over regulation.

As for the development and application of HIPPS, BP and Statoil are the leaders with the solution deployed on five projects each. Statoil has the largest number of separate systems deployed including the Kristen system, which currently operates under the highest pressure (13,000 PSI) and temperature (329°F) of HIPPS application. Shell has deployed HIPPS on the third-largest number of projects including the first operational system at the United Kingfisher project, followed by Petrobras and Chevron as the only other operators with current HIPPS applications (Figure 53).
Both Statoil and Shell have exclusively deployed the technology in the North Sea, with Petrobras exclusively employing it offshore Brazil.

**Subsea gas compression**

Subsea gas compression is the least-proven subsea processing technology, with no units currently in operation. The aim of this process is to install seabed compressors near the subsea wellheads to increase the pressure in gas fields to maintain stable flow to the surface. Subsea gas compression will move gas compression from surface and shore facilities to the seabed, allowing production rates at gas developments to remain at high levels despite declining reservoir pressures without the installation of additional or new facilities.

Statoil, which is currently the only operator implementing this technology, has successfully tested this technology utilizing its K-Lab project in near-field conditions and is intent on utilizing this technology on its Gullfaks, Ormen Lange and Asgard fields. While Gullfaks and Asgard are rather short step-outs from their hosts driven by a lack of available topside space, the Ormen Lange project is an all-subsea development. It is in these types of developments where the potential for growth in subsea compression is most likely.

Beyond the North Sea and projects such as Snohvit where all current developments are located, other areas where this technology will likely be utilized are Australia (on developments such as Chevron’s Gorgon project, which utilizes long subsea tiebacks to an onshore LNG facility) and the Middle East, where projects in Egypt and Israel utilize similar long subsea tiebacks to shore or platforms. BP, which has fields fitting this description in Egypt, has studied subsea gas compression.

**Subsea chemical and water injection**

Subsea chemical injection allows chemicals primarily utilized for flow assurance and corrosion protection to be distributed subsea; this prevents the need for larger numbers of umbilicals with greater complexities and a more complicated subsea arrangement.

Subsea chemical injection is increasingly viewed as part of the standard tool kit for the development of deepwater projects. Although it is less of a game-changing technology, subsea chemical injection still provides cost savings and a simplified seabed and topside arrangement.

The growing push into deeper waters and Arctic areas where flow-assurance challenges increase and the needs for chemical injection are thus amplified should help to push the growth of this technology. Additionally, the Brazilian pre-salt with its highly corrosive mix of CO2 and sulfur may be another area that spurs growth in this technology. These qualities should allow subsea chemical injection to see continued growth in the coming years.

All of the discussed operators except ExxonMobil have deployed subsea chemical-injection systems. Statoil again leads in the number of applications, with over 30. Total has utilized subsea chemical injection on 15 projects; BP has deployed systems on 15 projects as well, while Shell has utilized the technology five times with Chevron and Petrobras using the technology about the same amount.
Both Statoil and Shell have used this technology exclusively in the North Sea, while Petrobras has used it only in the Gulf of Mexico and Chevron exclusively in Asia. Only Total and BP have utilized subsea chemical injection in multiple regions with applications in the North Sea, Africa and the Gulf of Mexico for both. Total leads chemical-injection spending, with nearly $100m spent. Statoil has spent around $75m on this technology while BP has spent just over $50m.

**Pipeline, risers, umbilicals and power distribution**

As one of the most diverse areas of technology, pipelines, risers and umbilicals will likely see the most innovation and advancement over the long term. Overall, riser technology and pipeline technology both see about 40 percent of applications by number of projects, with umbilicals having approximately 20 percent. From a spending perspective, pipelines lead with around 50 percent, with risers at 30 percent and umbilicals again at around 20 percent.

Moreover, we expect the technologies under study to become increasingly important and believe the industry will see many moving from the novel technology basket to preferred technology applications in the coming years. The push into deeper waters and harsh operating environments including Arctic areas will lead this push, as flow-assurance challenges coupled with rising capital costs demand further innovation.

The primary focus for future flowline technologies is on the increased maturation of flow assurance. In the Arctic, for example, the ability to maintain fluid temperatures throughout a production system will be a very difficult task given the extreme temperatures of the region.

**Riser technology**

Riser technology is focused on floating production-storage and offloading units, specifically various technologies to deploy steel risers on these units. These technologies include riser towers (HRT), single-line offset risers (SLOR), and the deployment of steel catenary (SCR) and lazy wave risers on FPSOs. Steel risers are favored over the traditionally used flexible risers due to much lower acquisition costs. Integrated production bundles (IPB) can provide active heating, additional insulation, fiber-optic monitoring of temperature, gas lift and traditional umbilical functionality, allowing for easier installation and improved flow assurance.

**Pipeline technology**

Pipeline technology focuses on flow assurance, with electrically heated (EH) flowlines being the most-deployed technology. The driver for this technology is flow assurance in increasingly deeper water depths and due to longer offsets (from the host facility) as well as in colder regions, and the future focus on Arctic production will likely drive this and other Arctic flow-assurance technologies to be utilized more frequently. Other flow-assurance-related technologies include the ability to reel pipe-in-pipe (PIP) insulated flowlines, thus decreasing installation costs. Composite flexible flowlines, which utilize high-tech materials to reduce weight while increasing strength, also decrease installation cost.

Furthermore, Petrobras has recently shown a large commitment to the continued use of integrated production bundles (IPB) via a partnership with Technip. Under the terms of the agreement, Technip has built a new flexible product manufacturing center in Brazil, which will focus on high-end products like IPBs (Figure 53).
Other possible technological additions to future flowline technology will likely be focused on integrity management – leak detection, physical armoring, etc. These technologies again will be key enablers for Arctic developments.

Who is applying subsea technology

Petrobras is the leader in innovative pipeline and riser technologies, having utilized riser towers (on Cascade Chinook in the Gulf of Mexico) and integrated production bundles twice in Brazil (Technip supplied). Additionally, the company has used composite flexible flowlines and reeled pipe in pipe in Brazil along with leading the development of thermoplastic umbilicals including new crush-resistant umbilicals that can withstand the 2,200 meters or greater water depths of its recent pre-salt finds.

Shell has used both lazy wave steel risers and steel catenary risers for FPSO units in West Africa and South America, respectively. Additionally they have deployed electrically heated flowlines once in the North Sea. For Shell Park BC-10, Shell utilized Tenaris, Aker Solutions, Wellstream (SA) and Subsea 7 (SA) for manufacturing and installation services.

Total is focused on riser technology having used riser towers, integrated production bundles and steel catenary risers on FPSO units, all in West Africa, with a total of five applications. They have also conducted studies on direct electrical heating (DEH) pipelines. Additionally they are the only operator to deploy a full all-electric control umbilical, supplied by Technip, at their K-5F field in the Dutch North Sea. Total has patented the technology for direct electrical heating of flowlines and is presently installing and testing in collaboration with Technip a system offshore the UK on a project called ISLAY (as of December 2011).

Statoil has utilized electrically heated flowlines for flow assurance in the North Sea (Nexans supplied Direct Electrical Heating for links on Aasgard and Huldra) and is the leading operator in this technology with eight projects utilizing it, driven by the North Sea environment in which they conduct the majority of their projects. Additionally, Statoil has deployed a carbon-fiber rod umbilical (supplied by Aker Solutions) at their Q project in the Gulf of Mexico, which makes up part of the larger Independence Hub project with many operators participating.
BP has utilized innovative pipeline, riser and umbilical technology on three separate projects. West Africa has seen two utilizations with a riser tower (Technip and Subsea 7, formally Acergy) operating on Angola's Block 18 and carbon-fiber rod umbilicals (supplied by Aker Solutions) to be utilized on the soon to start up PSVM project, which is in Angola’s block 31. Additionally, BP has used direct electrically heated flowlines on the North Sea’s Skarv project.

ExxonMobil has also focused on the West Africa region with applications of both riser and umbilical technology in the region. The company has deployed riser towers twice, both on different phases of the Kizomba project, as well as utilizing steel catenary risers (supplied by Tenaris) on the Erha FPSO. Exxon has also used carbon-fiber rod umbilicals (supplied by Oceaneering Umbilical Solutions) on the Kizomba satellites project.

Power distribution and umbilical technology

Power distribution technology, one of the most challenging applications, is a key enabling technology for subsea processing, with power needs ever increasing for processing units. Power umbilicals for these projects are sometimes dedicated and sometimes integrated into a production umbilical. In the case of integrated umbilicals, greater and greater power usage has led to an increase in fiber-optic technology, as electrical interference decreases the effectiveness of traditional electrical communication. Due to the increasing power requirements driven primarily by subsea processing, subsea power distribution has been one of the more studied topics by operators as they look to ensure that the increasing requirements for the next generation of subsea processing systems can be met.

Topics of study include the ability to accurately provide proper voltage power supply at long step-outs, with the development of reliable wet mate-able connectors both for power and electrical optical connections. Subsea electric actuators and electrical insulation to prevent interference in high-voltage systems are also important topics that are under study to enable larger and more robust processing systems. The possibility also exists, as is the case on Total’s K-5F project in the Danish North Sea, that in the future electric and fiber-optic systems could replace hydraulics for subsea controls.

The use of high tech materials is also leading the way in production umbilical development. The umbilical technology studied is focused on very deepwater, with the two primary technologies being the integration of carbon-fiber umbilical rods to increase umbilical strength while adding minimal weight, and the usage of special crush-resistant thermoplastic tubing to enable the use of the thermoplastic umbilicals in water depths over two thousand meters.

Umbilical technology will continue to be driven by the increasing water depths of production and the associated challenges of weight and strength required. Whether through novel means that may be increasingly common such as the use of high-tech materials, eg, carbon fiber, to provide strength with little relative weight gain, or by the use of advanced crush-resistant materials in existing design, the increasing challenges of deepwater should continue to push umbilical designs to meet the ever-greater requirements.

As power requirements, and thus electrical interference, increase with the ever-greater power needed at the sea floor, fiber-optic technology should increasingly replace electrical communication as the method of choice. The ability to transmit the ever-greater power needs required by subsea
processing applications such as gas compressors will challenge technology as it currently stands, especially in the areas of connection, actuation and insulation. In the future, electric power coupled with fiber-optic communication may come to replace the standard electric hydraulic control system on which the subsea industry has relied.

Subsea technology key players

The companies that both innovate and adopt new subsea technologies should continue to be the most successful deepwater producers. The two clear leaders in terms of adopting new technology are Statoil and Petrobras, based on our research. Statoil and Petrobras lead our rankings due to their:

- Commitment to a diversity of subsea technology systems
- Extensive research programs
- Willingness to use unproven technology, and
- Capital commitments to utilizing subsea technology

Perhaps most impressive is their willingness to rapidly utilize technologies that succeed instead of waiting on the results of one system.

Major international oil company commitments to innovative subsea technologies exceed US$3.5bn in the near term. Over 145 projects have been identified for R&D funding led by Statoil, BP and Total (Figure 54).

Petrobras

Petrobras is the worldwide leader in the number of subsea applications of subsea processing technology. Petrobras has, for the most part, focused on subsea boosting (the company is leading both in number of projects and pumps deployed), utilizing this technology primarily for the heavier-oil non-presalt traditional Brazilian fields. However, Petrobras has also applied this technology to the Cascade Chinook project in the Gulf of Mexico. While existing projects have been mostly greenfield applications, Petrobras has also used this technology in existing fields. Quest projects that brownfield opportunities will continue to expand as existing fields age. Petrobras is likely to utilize brownfield boosting on most of their large, conventional fields such as the Marlim and Roncador fields due to the large production units in place.

The large number of wells on these fields could also lead to significant growth in the number of pumps deployed. Historically, Petrobras has favored traditional electrical submersible pumps (“ESPs”) placed on the seabed;
however, they have also utilized helico-axial pumps, centrifugal pumps, and twin-screw pumps. Additionally, Petrobras has utilized subsea separation and subsea raw-water injection technologies on their fields offshore Brazil.

Petrobras’ separation efforts have been focused primarily on greenfield water separation in traditional fields, and this is likely to continue to be the case with additional systems deployed in brownfield situations as their large traditional oil fields enter the later stages of their development cycles. Petrobras has spent over US$500m on subsea processing technologies, making the company the number-two overall purchaser in dollar terms of subsea processing technology behind Statoil.

**Statoil**

Statoil, while having slightly fewer applications of subsea processing technology than Petrobras, leads the industry in subsea processing technology spending, with well over US$1bn spent, or to be spent, in the near-term future (four to five years). Additionally, Statoil is the only operator to employ all four facets of subsea processing including subsea boosting, subsea separation, subsea raw water injection and subsea gas compression. Statoil has traditionally deployed processing technologies primarily in the North Sea, but the company has also utilized the technology for the Lufeng project offshore China.

Statoil has employed subsea processing on both brownfield and greenfield projects. The company has also deployed some of the largest and most complex processing systems including Tordis, which employs separation, boosting and raw-water injection for enhanced oil recovery – and is one of the largest subsea processing systems ever deployed.

Statoil favors more advanced multiphase pumps, with centrifugal pumps being the most deployed system for the company. Additionally, Statoil is the only company to be in the process of deploying subsea gas compression technology with numerous test projects and intends to employ the technology on the Asgard, Gullfaks, and Ormen Lange fields to further enhance the company’s recovery factor at these fields.

This technology enables continued economical production from mature gas fields in cases of unavailable or uneconomic topsides capacity, and should continue to grow in importance not only in Norway (with its importance as a gas supplier for Europe), but also worldwide due to the maturation of subsea fields and proliferation of long gas tiebacks.

The next likely Statoil candidate for subsea processing technology will be the Snohvit field in the Norwegian sector of the North Sea. Snohvit will be compromised of a long gas tieback to an LNG production barge. Subsea gas compression will likely be the only option for this field, as the harsh Arctic conditions at the field likely prohibit any economical floating structure. With their lease holdings in the Barents Sea and involvement in other Arctic areas, Statoil will likely find themselves using subsea processing technology to facilitate future subsea-to-beach developments in Arctic areas where ice and/or weather conditions make the use of floating or fixed structures unfavorable.

**Shell**

Shell has utilized subsea processing five times on three projects and is the only operator to have utilized this technology in three different hemispheres; Shell is estimated to have spent about US$350m on processing systems. The
company has shown a focus on combined separation and boosting systems and has so far only used processing technology on new projects. Shell has used boosting as the sole subsea processing technology on the BC-10 (Shell Park) project in Brazil.

Shell has employed a combined separation and boosting system to recover heavier, lower-drive oil in the Gulf of Mexico’s Perdido development and Draugen in the Norwegian sector of the North Sea. Recently, the company has shown a desire to employ ESPs for subsea boosting and/or pumping instead of a helicon-axial pump. In the future, Shell is likely to continue to focus on separation and boosting due to their focus on oil projects in deepwater. Most of their opportunities lie in the lower tertiary of the Gulf of Mexico along with further opportunities in Brazil’s heavy oil basins.

Total also favors combined separation and boosting projects on new fields with West Africa’s Pazflor (brought on line in late 2011) and Clov (under development) utilizing these types of systems (Figure 55). These large, complex systems are developed to allow the economical tapping of large footprint, low-drive fields with high well counts. The size of these systems (coupled with the high-cost environment when the Pazflor system was contracted) leads to spending levels in excess of US$500m for subsea processing systems for Total.

In the future, Total is expected to continue to focus on these large greenfield separation and boosting systems for African projects, with other opportunities in Africa for brownfield applications after their traditional method of water injection and large numbers of infill wells become unable to continue to deliver economic recovery. With the potential for very important increased recovery from these fields, Total is poised to remain a market leader in the application of subsea processing technology.
BP

British Petroleum has deployed three subsea processing systems with two in the North Sea (including one West of Shetlands) and one a brownfield pumping application in the King field in the Gulf of Mexico. All BP systems are solely boosting systems, with helico-axial pumps deployed on two occasions and twin-screw pumps utilized in one. While having no bearing on the company’s commitment to subsea processing, it is worth noting the difficulties that were experienced with BP’s King Pump project in the Gulf, with reported leakage leading to frequent downtime.

While no specific data is available outside of BP, market sources indicated a leak was found after the startup of the pump, and at present it is believed that this system is no longer in use. Additionally, while there – again – is not a quantifiable manner to determine the cause of these problems, it is worth noting that this system was the first pump manufactured by Borneman for Aker Solutions.

In the future BP should be a more active player in the development and use of subsea processing systems, with opportunities for greenfield boosting in the Gulf of Mexico lower tertiary, deepwater Caspian Sea and West Africa. Of special interest may be the manner by which the company develops its Kaskida field in the Gulf of Mexico’s Keathley Canyon basin (KC 292). The reservoir at Kaskida is known to be very challenging and will require significant boosting systems due to low energy in the wells. BP’s lower tertiary Tiber discovery, while not yet to the design phase, could be one of the largest boosting applications in history.

Furthermore, brownfield boosting in the Gulf of Mexico and Africa will likely be a factor as many of the company’s large projects progress through their life cycles (Thunder Horse, as an example will need additional production to maintain high utilization of the semi-submersible host facility). BP is also poised to employ subsea gas compression in Egypt as BP holds numerous opportunities to develop large gas fields in the region, and is known to have studied very large gas compression systems and their power requirements.

ExxonMobil

ExxonMobil has only utilized subsea processing (in the form of subsea boosting) one time historically on the Topacio project offshore Equatorial Guinea, which began production in 1997. The Topacio project utilizes three helico-axial pumps to achieve better production rates. The long gap in deployments will likely be broken at some point in the future as Exxon continues to move into deepwater. Many of the deepwater prospects in Exxon’s portfolio will require additional energy to boost the performance of the reservoirs.

The most likely near-term candidates for Exxon are the company’s Gulf of Mexico lower tertiary fields such as Hadrian and Julia. Lower tertiary fields in the Gulf have been found to maintain a relatively low gas-to-oil ratio, which necessitates boosting systems to deliver energy to the flow of hydrocarbons.

The company will likely also have many opportunities for brownfield deployment of pumping systems in West Africa. Exxon has been one of the leading companies in the development of large offshore developments in the region. As such, the maturation of these fields will pose prime candidates for the increased recovery of resources. This will allow Exxon to realize a potential increase in project economics given the long-term oil price forecast.
Chevron

Of leading major operators, Chevron is the least-advanced regarding current applications of subsea processing technology.

Despite a slow adoption rate, Chevron is expected to eventually become a major adopter of boosting systems as it continues to develop lower tertiary projects along the lines of the world-class Jack and St Malo development supplied by Cameron. Chevron will follow the development of the Jack and St Malo fields with the development of the Big Foot prospect – which will likely be its second deployment of subsea processing (boosting) technology.

Chevron’s continued focus on the lower tertiary should see an increasing number of these systems in the coming years. Additionally, Chevron may be one of the next companies to utilize subsea gas compression as the company deals with maturity issues at its large developments currently underway, such as subsea-to-onshore LNG developments in Australia - Gorgon and Wheatstone. In these cases, plans for later-life gas compression are already underway and subsea technology will provide viable alternatives to the fabrication and installation of a floating gas-compression units. This approach has already made significant progress with Statoil, with which Chevron has a technology-sharing joint-venture agreement.
**Appendix 1: Subsea equipment suppliers**

All of the major subsea equipment manufacturers supply far more than just subsea trees and attribute much of their success to that diversity. This diversity can help each supplier solidify their place in the market and establish long-term relationships with oil companies, which is key in this industry. When it comes to equipment that must successfully operate in thousands of meters of water, under stressful conditions for extended periods of time, oil companies can be tentative when it comes to considering new or different suppliers. It is very common to see “preferred supplier relationships” in this market, if not formal frame agreements. This leads the industry to be one of the toughest for new entrants to break into the market. The oil companies are, for the most part, like-minded in keeping a supplier if the product continues to perform to expectations.

### Aker Solutions

**Aker subsea facilities**

<table>
<thead>
<tr>
<th>Facility production</th>
<th>Facility location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsea production systems</td>
<td>Curitiba, Brazil</td>
</tr>
<tr>
<td>Subsea production systems</td>
<td>Tranby, Norway</td>
</tr>
<tr>
<td>Subsea production umbilicals</td>
<td>Moss, Norway</td>
</tr>
<tr>
<td>Subsea production umbilicals</td>
<td>Mobile, Alabama, USA</td>
</tr>
<tr>
<td>Subsea production systems and umbilicals</td>
<td>Pulau Indah (KL), Malaysia</td>
</tr>
</tbody>
</table>

*Source: Quest Offshore Resources, Inc*

Aker Solutions is a subsidiary of its holding company, Aker ASA. Aker Solutions has aggregated annual revenue of approximately NOK35bn and employs approximately 17,000 people in about 30 countries. Aker Solutions constitutes several business units aside from umbilicals such as engineering, subsea and drilling technology.

**Technology focus**

Ongoing research and development efforts strive to build upon previous subsea technology developments, particularly in the areas of subsea processing such as subsea gas compression, separation and boosting services. Subsea Technology solutions developed and marketed in the period of 1990-2011 include the acquisition of controls, wellhead and subsea tree technology, deepwater high-pressure/high-temperature (HPHT) development, subsea separation, compression, pumping and workover system tie in, and oilfield services and drilling riser design. In the period of 2012-15, Aker strives to offer full-service technical solutions including a full suite of vertical subsea trees, next-generation pump, separation, compact compression, all electric and sixth-generation control systems. Additionally, further development of service offerings centered on condition monitoring and production optimization in addition to deepwater workover systems are technology-development priorities.

Aker Solutions is a Norwegian-based subsea supplier whose bright spot in the market lies in subsea controls and steel-tubed subsea production umbilicals. Despite not having as strong a showing ongoing in the subsea tree market as Cameron or FMC Technologies, Aker Solutions’ strategy is to align themselves...
with national oil companies that have not had to rely extensively on outside funding. They also recognize the importance of the independent oil company community, which aims for minimalistic subsea developments but are open-minded and quicker to act on their subsea developments. Over 60% of their awards from international (major) oil companies came from Total off Angola for their Dalia development. While their foundation of demand does not come from the international oil-company community, the awards they do win from them are large and key for the regions in which they are active. Aker Solution’s major contracts from international oil companies include one from Total off Angola and another for Eni offshore Norway. These two awards made up over 80% of their awards to this oil-company sector. Aker is also aggressively pursuing subsea processing applications and have a number of awards and pilots in place for Norwegian projects looking to utilize this innovative suite of technologies (ie, Statoil’s Asgard Gas Compression and Shell’s Ormen Lange Gas Compression Pilot).

Aker’s last peak of control awards was in 2008

Aker Solution’s market share of global subsea control awards

<table>
<thead>
<tr>
<th>Year</th>
<th>Aker Solutions</th>
<th>Other suppliers</th>
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<tbody>
<tr>
<td>2000</td>
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<td>2010</td>
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<td>180</td>
</tr>
<tr>
<td>2011</td>
<td>230</td>
<td>170</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

Aker does not sell thermoplastic umbilicals

Aker’s umbilical business unit is unique from several other umbilical manufacturing entities in that they produce steel-tube umbilicals exclusively in lieu of thermoplastic. The umbilicals business area, however, incorporates a wide range of technologies in addition to steel-tube umbilical systems such as hydraulic flying leads, power umbilicals, integrated production umbilicals (IPU), flowline heating systems/direct electric heating (DEH), HV subsea cables, composite rods and tubular and top tension risers. Since 1993, more than 3,800 kilometers of Aker Solutions umbilical product have been installed around the world.

Technology focus

One technology recently employed by Aker Solutions is the application of carbon-fiber rods in deepwater umbilicals utilized in water depths of 2,000 meters or more. The carbon-fiber rods provide enhanced mechanical properties for the umbilical and have been utilized in Independence Hub (2469 MSW), Petrobras operated Cascade-Chinook project (2499 MSW) and BP’s Block 31 PSVM project in offshore Angola (1804 MSW).
Aker had a record umbilical year in 2010

A meaningful portion of Aker’s business is from national oil companies

Cameron has five subsea facilities

Cameron sells rig equipment in addition to subsea equipment

Aker market share of subsea production umbilicals

km of SPU (All types)

Aker Solutions  Other

Aker global subsea market share by operator type

(No. of subsea trees)

Independent  Major  National

Cameron

Cameron subsea facilities

<table>
<thead>
<tr>
<th>Facility Production</th>
<th>Facility Location</th>
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<tr>
<td>Subsea production systems</td>
<td>Celle, Germany</td>
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<tr>
<td>Subsea production systems</td>
<td>Burwick, LA, USA</td>
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<tr>
<td>Subsea production systems</td>
<td>Macae, Brazil</td>
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<tr>
<td>Subsea production systems</td>
<td>Pelsabuhan Tanjung Pelepas, Malaysia</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

Cameron is a leading provider of flow-equipment products, systems and services to the worldwide oil, gas and process industries. Cameron employs approximately 18,000+ personnel globally in over 300 locations. The company is headquartered in Houston, Texas. Global manufacturing, engineering, and sales and service networks cement Cameron’s global position in the global offshore oil and gas industry.

Cameron is a leading oilfield supplier specializing in pressure and flow-control equipment, including wellheads, subsea trees, blowout preventers, valves and compression equipment (off and onshore). We expect Cameron International’s earnings will grow with the subsea market, with support from the company’s short-cycle businesses from continued activity in the US shale plays and rig upgrades. In the last five years, Cameron’s share of the subsea market increased 22% compared to the previous five years and we expect Cameron to maintain their strong market position. Cameron has dedicated significant resources to the subsea market because of anticipated market growth. In 2010 Cameron spent US$65m (33% of total capital spending) to expand its subsea systems facility in Malaysia, establish a new subsea aftermarket center in Western Australia and expand two subsea facilities in West Africa. We expect Cameron to open a new subsea aftermarket facility in China in 2012 to support projects in the South China Sea. On the heels of Petrobras’ new tranche of subsea tree awards, Cameron is expected to invest up to US$170m in Brazil.

Cameron recently expanded its subsea facility in Malaysia

Average market share of 29% based on high share of orders in 2009

Cameron International’s share of subsea trees

Source: Quest Offshore Resources, Inc

Technology focus

Cameron is at the forefront of all-electric control technology as evidenced by their development of the second-generation CameronDC system. All-electric control technology eliminated the hydraulic control elements utilized in subsea production umbilicals. The potential advantages of all-electric controls include more immediate feedback and control, longer offset distances, greater water depths, decreased environmental risk due to the elimination of hydraulic fluids, reduced costs due to simplification of the umbilical and faster response times. Second-generation technology builds upon the pilot CameronDC all-electric control system that is currently operational as a pilot in the Total operated K-5F gas field in the Dutch North Sea.
Market approach
Cameron is a Houston-based subsea solutions provider whose historical awards have been driven by the Golden Triangle and the company has strong relationships with all three oil company types (international, independent and national). Among the major subsea tree manufacturers, Cameron has the most equal spread of customer types. This diversity among its customer base is an advantage for Cameron in maintaining it position among the top-two global suppliers.

Cameron Int subsea tree awards by oil company type and region (2000-3Q11)

Overall, they have been the market leader in supplying trees to Petrobras off Brazil. This top spot was solidified when they were awarded a contract for the supply of 138 standard trees in 2009/2010 worth US$500m.

Petrobras’ tree demand by major manufacturer (2000-3Q11)

Cameron’s success in the Golden Triangle is a strong strategy as Brazil and West Africa tend to produce high-volume and high-value subsea system awards. In the US Gulf of Mexico Cameron has historically had strong relationships with ATP, Chevron, Eni, Noble Energy and BHP Billiton as well as having a frame agreement with BP for new subsea developments. Looking into the future, these six oil companies have over 20 unique subsea developments in line for execution, which speaks positively to Cameron’s opportunities in the region.
Cameron Int top oil company clients in US Gulf of Mexico (2000-3Q11)

<table>
<thead>
<tr>
<th>Company</th>
<th>No. of subsea tree awards</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATP</td>
<td>15</td>
</tr>
<tr>
<td>BHP Billiton</td>
<td>20</td>
</tr>
<tr>
<td>Chevron</td>
<td>30</td>
</tr>
<tr>
<td>Eni</td>
<td>15</td>
</tr>
<tr>
<td>Noble Energy</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

Subsea revenues are now greater than 20% of total

Cameron Int subsea revenues as % of total

Source: Company reports

FMC Technologies has six subsea facilities

<table>
<thead>
<tr>
<th>Facility Production</th>
<th>Facility location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsea production systems (control systems)</td>
<td>Kongsberg, Norway</td>
</tr>
<tr>
<td>Subsea production systems</td>
<td>Dunfermline, Scotland</td>
</tr>
<tr>
<td>Subsea production systems</td>
<td>Houston, Texas, USA</td>
</tr>
<tr>
<td>Subsea production systems</td>
<td>Rio de Janeiro, Brazil</td>
</tr>
<tr>
<td>Subsea production systems</td>
<td>Singapore</td>
</tr>
<tr>
<td>Subsea production systems</td>
<td>Malaysia</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

FMC Technologies is the world leader in subsea tree manufacturing and should benefit from the growth in subsea demand in the future. The company has approximately 13,500 employees and operates 27 production facilities in 16 countries. FMC Technologies’ product and service offerings are divided into the following product areas: Subsea Systems, Surface Wellhead, Fluid Control, Loading Systems, Measurement Solutions, Material Handling Solutions,
Separation Systems and Blending and Transfer Systems. In the 1980s, FMC Technologies made its initial investment in its subsea wellhead and completion systems product lines. Today, the company has several strategic alliances and frame agreements that have led to a consistent flow of awards. In 4Q11, FMC Technologies announced three subsea awards, including a US$325m subsea systems contract for Chevron’s Wheatstone project. Another award was from BP for additional trees offshore Angola and for which we believe FMC has already supplied more than 40 trees. FMC expects both BP and Chevron will be two of the top-three companies awarding tree awards in the next five years (476 trees in total), with the top awarder Petrobras (405 trees). According to FMC Technologies, there are at least 17 subsea project opportunities over the next 15 months that will lead to approximately 320 subsea tree orders. As the market leader, we believe FMC Technologies will compete for most of these projects.

Subsea systems incorporates a wide range of equipment and service provided throughout the life of a field development in order to safely and efficiently explores, drill and develop offshore oil and gas fields. In addition to subsea trees, FMC Technologies designs, manufactures and services drilling systems, controls, manifold pipeline systems, tie-ins, flowlines, chokes and flow modules. Additionally, FMC is also an active pioneer in subsea processing systems, gas compression, well intervention services and production monitoring and optimization.

Market approach

Since 2000, FMC Technologies has been the long-term market leader for subsea systems awards with over 37% of subsea tree awards during this time.

FMC Technologies focuses on high-value opportunities where they can provide the complete subsea systems solution and have been very successful with this strategy. The other half of its success comes from maintenance of long-term relationships with its highly diverse customers so that during times of fewer high-capital developments, they still have a strong foundation of awards for smaller greenfield or ongoing brownfield developments. This second strategy has helped them maintain a strong market position in the past few years when there have been far fewer mega West Africa projects than in previous years.

Current trees provide foundation for future trees

Fewer mega projects will mean FMC will focus on infill projects

1 Only includes major subsea tree manufacturers.
Source: Quest Offshore Resources, Inc; 3,996 subsea trees
New independent customers appear willing to place orders with FMC before other companies.

The North Sea is a stable area of demand for FMC.

FMC has meaningful market share across regions.

Much like Cameron, FMC Technologies has found the most success in the Golden Triangle as they pursue high-value awards in those regions. One key difference between the two suppliers is FMC Technologies’ leading market position in supplying subsea trees to the North Sea. As mentioned previously, the North Sea is one of the most stable bases of subsea tree demand, and as such is a key area for the suppliers to ensure they have a strong relationship with the oil companies operating in the area. With the exception of Brazil, FMC Technologies has been the long-term market leader in every other major geographic region since 2000.
Subsea revenue is still over 60% of FMC’s total

FMC Technologies subsea revenues as % of total

Source: Company reports

FMC has been able to hold onto market share

FMC Technologies share of subsea trees

Source: Quest Offshore Resources, Inc

GE

GE subsea facilities

<table>
<thead>
<tr>
<th>Facility production</th>
<th>Facility location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsea production systems</td>
<td>Houston, Texas, USA</td>
</tr>
<tr>
<td>Subsea production systems</td>
<td>Aberdeen, Scotland</td>
</tr>
<tr>
<td>Subsea production systems</td>
<td>Sao Paulo, Brazil</td>
</tr>
<tr>
<td>Flexible flowline</td>
<td>Niteroi, Brazil</td>
</tr>
<tr>
<td>Subsea production systems</td>
<td>Singapore</td>
</tr>
<tr>
<td>Flexible flowline</td>
<td>Newcastle-upon-Tyne, UK</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

GE has six subsea facilities

GE provided a subsea inspection tool for pipelines to BP

GE invested approximately US$11bn in the energy sector in 2011 and hopes to integrate these acquisitions in 2012. GE expects a 20% growth rate in the subsea systems market (2011-14 Cagr) and currently offers subsea trees and wellheads, subsea power and processing, controls, manifolds, flexible risers, flowlines (Wellstream), specialty connectors and pipes and floating production systems. Key subsea technology breakthroughs with customers include the first subsea compressor for Statoil and a remote monitoring inspection tool.
for subsea pipelines for BP. GE reported receiving approximately US$14bn of oil and gas orders in 2011; GE’s total backlog in 2010 was US$67bn and in 3Q11 GE had total revenue of US$35bn.

The acquisition of Vetco Gray and its legacy of oil and gas companies provided a strong basis for GE Oil and Gas and their burgeoning activities in the expanding subsea production technology arena. Upstream applications of GE Oil and Gas products include gas reinjection, gas lift, gas processing & treatment, water injection, liquefied natural gas (LNG), gas export, power generation and subsea applications. Products include centrifugal pumps, compressors, gas turbines, subsea controls and informatics, subsea power and processing systems, subsea trees, subsea manifolds, subsea wellheads and wireline systems among others.

**Market approach**

GE Oil & Gas’ success in the subsea market comes mainly from their wellhead business, with strong showings in the subsea tree and control market as well as aftermarket services. Recent success has stemmed from awards from Petrobras. Major contracts for subsea wellheads were awarded to GE Oil & Gas in 2009 and 2011 valued at US$50m for 171 subsea wellheads and US$250m for 250 subsea wellheads, respectively. In addition, they were awarded a four-year service contract to deliver repairs, maintenance and retrofits to Petrobras subsea equipment in the Campos Basin valued at US$120m. They also have a frame agreement with OGX off Brazil for the supply of subsea trees. With OGX’s aggressive development strategy in the future, this relationship is a valuable one for GE Oil & Gas.

**GE subsea tree**

Within the subsea tree market, regionally, most of GE Oil & Gas’ awards have come from the North Sea.
Within the North Sea, the overwhelming majority of awards are for the UK sector, of which most of the subsea trees were ordered from independent oil companies. A key customer relationship trend for GE Oil & Gas’ historical awards is they have 36 unique independent oil-company clients, second only to FMC Technologies with 40. Independent oil companies typically have a shorter project-cycle timeline than major or national oil companies, with smaller but sometimes more numerous subsea developments. The downside of having so much of its customer base with the independent oil companies is the oil companies’ high sensitivity to global economic events and oil and natural-gas prices.

GE may continue to acquire businesses to establish market share for future infill projects

GE has multiple relationships with independent oil companies

GE has sold most of its trees in the North Sea to UK fields

GE has tried to achieve a 20% market share

GE’s share of subsea trees

Source: Quest Offshore Resources, Inc; 980 subsea trees

Source: Quest Offshore Resources, Inc; 328 subsea trees

Source: Quest Offshore Resources, Inc
**Oceaneering**

**Oceaneering subsea facilities**

<table>
<thead>
<tr>
<th>Facility production</th>
<th>Facility location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsea production umbilicals</td>
<td>Rossyth, Scotland</td>
</tr>
<tr>
<td>Subsea production umbilicals</td>
<td>Panama City, FL, USA</td>
</tr>
<tr>
<td>Subsea production umbilicals</td>
<td>Ilha da Conceicao, Nietroi, Brazil</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

Oceaneering is a leading underwater services contractor focusing on the deepwater remotely operated vehicles (ROV) business and the subsea products business, two very attractive segments in the oilfield services industry. As a result of this focus, Oceaneering is the most leveraged company to the subsea deepwater segment discussed herein. The influx of newbuild floaters entering the market over the next few years presents vast opportunities for both Oceaneering’s ROV fleet and its subsea products segment. ROVs perform work that divers can’t perform for rigs and offshore construction, and can work in water depths of more than 10,000 feet. As more deepwater exploration and development takes place, we believe the need for these ROVs will inevitably grow. OII indicates that it has approximately 35% of the ROV market; competitors in the ROV market include Subsea 7, Sonsub, Fugro, Canyon and others. The company has approximately 8,200 employees in 21 countries and boasted second-quarter 2011 revenue of US$545.8m.

**Oceaneering remotely operated vehicle**

Source: Oceaneering

In 2010, Oceaneering renamed their umbilical division from Multiflex to Oceaneering Umbilical Solutions (OUS). The division has over thirty years of providing subsea products and engineered services and has delivered over 4,300 kilometers of umbilical product. The division has the capability to manufacture thermoplastic, steel-tube and subsea power umbilicals. OUS has an impressive umbilical project portfolio that includes Shell BC-10, ExxonMobil Kizomba and Shell Gumusut Kakap to name a few.
Technology focus
Oceaneering recently invested approximately US$2m in a new Test, Qualification and Reliability (TQR) facility at their Rosyth, Scotland operations. The TQR group provides an extensive range of testing and qualification services including combined torsion balance and tension testing, impact testing, axial compression testing, reliability analysis as well as strain testing and measurement.

Within the subsea production umbilical (SPU) market, Oceaneering Umbilical Systems plays an integral role in global supply with an average of 37% market share since 2000. Oceaneering has production facilities in Scotland, Florida and Brazil and manufactures both steel-tubed and thermoplastic-hosed SPUs.

Oceaneering Umbilical Solutions’ global SPU market share (2000-3Q11)

<table>
<thead>
<tr>
<th>Year</th>
<th>Oceaneering Umbilical Solutions</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>300</td>
<td>377</td>
</tr>
<tr>
<td>2001</td>
<td>440</td>
<td>377</td>
</tr>
<tr>
<td>2002</td>
<td>426</td>
<td>377</td>
</tr>
<tr>
<td>2003</td>
<td>377</td>
<td>377</td>
</tr>
<tr>
<td>2004</td>
<td>420</td>
<td>377</td>
</tr>
<tr>
<td>2005</td>
<td>418</td>
<td>377</td>
</tr>
<tr>
<td>2006</td>
<td>505</td>
<td>377</td>
</tr>
<tr>
<td>2007</td>
<td>573</td>
<td>377</td>
</tr>
<tr>
<td>2008</td>
<td>745</td>
<td>377</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

Oceaneering’s umbilical market share success stems from its strong presence in the US Gulf of Mexico and offshore Brazil, representing 58% of the demand base since 2000. All of its work in the US Gulf of Mexico has been steel-tubed SPU as thermoplastic-hosed product is not used in the area due to challenging ocean characteristics and the deep water depths.

While Brazil is also expected to see a slight uptick in demand for steel-tubed umbilicals, thermoplastic solutions are still expected to dominate the Brazilian market and are preferred by Petrobras. Oceaneering, the largest umbilical manufacturer in Brazil, is well poised to seize a large portion of orders from Petrobras’ multi-year demand for subsea production umbilicals.

Brazil’s SPU demand KM 2006-16E

<table>
<thead>
<tr>
<th>Year</th>
<th>Brazil</th>
<th>Rest of world</th>
<th>Brazil % of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>300</td>
<td>1,152</td>
<td>21</td>
</tr>
<tr>
<td>2007</td>
<td>49</td>
<td>918</td>
<td>5</td>
</tr>
<tr>
<td>2008</td>
<td>377</td>
<td>856</td>
<td>31</td>
</tr>
<tr>
<td>2009</td>
<td>440</td>
<td>533</td>
<td>45</td>
</tr>
<tr>
<td>2010</td>
<td>426</td>
<td>1,359</td>
<td>24</td>
</tr>
<tr>
<td>2011</td>
<td>357</td>
<td>1,202</td>
<td>23</td>
</tr>
<tr>
<td>2012</td>
<td>418</td>
<td>1,265</td>
<td>25</td>
</tr>
<tr>
<td>2013</td>
<td>505</td>
<td>1,648</td>
<td>23</td>
</tr>
<tr>
<td>2014</td>
<td>573</td>
<td>1,832</td>
<td>24</td>
</tr>
<tr>
<td>2015</td>
<td>745</td>
<td>1,931</td>
<td>28</td>
</tr>
</tbody>
</table>

Note: SPUs include both steel-tubed and thermoplastic-hosed umbilicals.
Source: Quest Offshore Resources, Inc

Petrobras has an affinity for thermoplastic-hosed SPU due to the lower cost to manufacture its lighter weight and ability to be re-used on multiple fields. Due to the significant demand for thermoplastic-hosed product from Petrobras as well as high levels from the North Sea in 2000-3Q11, Oceaneering produces more thermoplastic-hosed product than steel-tubed.
Oceaneering has a meaningful thermoplastic market share

Oceaneering Umbilical Solutions’ SPU market share by type (2000-3Q11 4,300KM)

<table>
<thead>
<tr>
<th>Material</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>39%</td>
</tr>
<tr>
<td>Thermoplastic</td>
<td>57%</td>
</tr>
<tr>
<td>SS Power</td>
<td>4%</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

Oceaneering is levered to the subsea market

Oceaneering subsea revenues (including ROV revenues) as % of total

<table>
<thead>
<tr>
<th>Year</th>
<th>Subsea Market Revenues as % of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>40</td>
</tr>
<tr>
<td>2005</td>
<td>45</td>
</tr>
<tr>
<td>2006</td>
<td>50</td>
</tr>
<tr>
<td>2007</td>
<td>55</td>
</tr>
<tr>
<td>2008</td>
<td>60</td>
</tr>
<tr>
<td>2009</td>
<td>65</td>
</tr>
<tr>
<td>2010</td>
<td>70</td>
</tr>
<tr>
<td>LTM</td>
<td>75</td>
</tr>
</tbody>
</table>

Source: Company reports

Technip

Technip has six subsea facilities

<table>
<thead>
<tr>
<th>Facility Production</th>
<th>Facility Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsea production umbilicals</td>
<td>Newcastle, UK (FlexiFrance)</td>
</tr>
<tr>
<td>Subsea production umbilicals</td>
<td>Lobito, Angola (AngoFlex)</td>
</tr>
<tr>
<td>Subsea production umbilicals &amp; flexible pipe</td>
<td>Tanjung Langsat, Malaysia (AsiaFlex)</td>
</tr>
<tr>
<td>Flexible flowline</td>
<td>Le Trait, France (FlexiFrance)</td>
</tr>
<tr>
<td>Flexible flowline</td>
<td>Vitoria, Brazil (FlexiBras)</td>
</tr>
</tbody>
</table>

Source: Quest Offshore Resources, Inc

Technip also engineers floating platforms

Technip’s activities in subsea cover the design, manufacture and installation of rigid and flexible subsea pipelines and umbilicals. Technip also engineers and fabricates floating platforms for deepwater. Approximately 22% of Technip’s current backlog is from deepwater (>1,000 meters).

Technip is an incredibly diverse member of the deepwater supply chain, providing engineering services, fabrication services, FPS construction services and installation services, to name a few. Within the SPU fabrication market, Technip has a global market share average of 27% since 2000.
Technip has a diverse set of products and services for deepwater exploration

**Top global installation contractors by KM installed (2000-15E)**

- **Saipem**: Highly significant in Africa/Medit.
- **Subsea 7**: Moderate in Asia Pacific/Middle East and North America.
- **Technip**: Significant in North Sea/Arctic and South America.
- **Allseas**: Significant in Africa/Medit.
- **Other**: Includes: Helix, Horizion, Hyundai. Note: Includes history from 2000-11 and awards for future installation 2012-16. Source: Quest Offshore Resources, Inc

Technip’s global activities span three business segments: Subsea, Offshore and Onshore. The company boasts a regular workforce of 23,000 employees operating out of 48 countries and 2010 revenues of more than €6bn. Technip’s umbilical division, known as Technip Umbilical Solutions, manufactures both steel and thermoplastic umbilicals. Technip has advanced installation capabilities and vast experience from their fleet of 43 high-specification marine installation and construction support vessels. Both the Sunrise 2000 and the Deep Pioneer are examples of reel lay vessels that Technip utilizes for both flexible flowline and umbilical installation. The recent acquisition of Global Industries further strengthens the group’s overall installation capabilities and provides the company with leverage across several classes of assets. In short, the ability to couple umbilical production, comprehensive installation services, engineering and project management expertise gives Technip a competitive advantage over competitors.

**Technip high-specification marine construction vessels**

<table>
<thead>
<tr>
<th></th>
<th>Derrick pipelay</th>
<th>Deepwater pipelay</th>
<th>Heavy-lift DCV</th>
<th>Pipelay trunkline</th>
<th>Reel lay</th>
<th>Subsea construction</th>
<th>Other²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technip¹</td>
<td>4</td>
<td>7</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>Rest of competitive fleet³</td>
<td>7</td>
<td>14</td>
<td>10</td>
<td>5</td>
<td>18</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Technip % share (main competitors)</td>
<td>36.4</td>
<td>33.3</td>
<td>0.0</td>
<td>16.7</td>
<td>25.0</td>
<td>55.0</td>
<td>63.6</td>
</tr>
</tbody>
</table>

¹ Combined assets from Acergy Merger. ² "Other" Category includes: MSV/DSV/ROV and intervention vessels. ³ "Rest of competitive fleet" includes: Allseas, EMAS AMC, Heerema, Helix, McDermott, Saipem, Sea Trucks Group, Subsea. Source: Quest Offshore Resources, Inc

**Technology focus**

Technip is in the process of developing a high-tensile aluminum core to replace traditional copper power cores. The aluminum core provides the benefits of improved mechanical properties without adding the significant weight of a traditional copper cable. Technip-Duco is yet to use the core on an installed development and the patented technology remains in the developmental phase.
Technip’s global SPU market share (2000-3Q11)

Technip is a dynamic player in the global umbilical market, supplying over 3,300km of product since 2000. Technip’s market-share strength in umbilicals lies in the North Sea and West Africa, which represents almost 60% of their awards since 2000. With West Africa dominated by major international oil companies and the North Sea dominated by smaller independent oil companies, it is no surprise to see Technip’s awards coming almost equally from the two oil-company communities. This trend results in Technip having a highly diverse customer base within the SPU market, which is a winning strategy in a market that can be as volatile as this one. Technip and Oceaneering have a similar unique customer count of 60 and 61, respectively. This strategy has definitely helped these two players stay on top of global market share.

Number of oil company clients per major SPU supplier (2000-3Q11)

West Africa favors steel tubes

Much like the dichotomy between the oil companies operating in West Africa and the North Sea, each region favors different types of SPU. West Africa leans heavily on the steel-tube supply chain for their often complicated SPUs. The North Sea, on the other hand, utilizes more thermoplastic-hosed product for their typically shallower developments operated by independent oil companies, which are far more likely to use thermoplastic-hosed SPU when they can as a cost-saving strategy. With Technip’s strong position in each of these regions, the breakdown of product they produce is nicely balanced between steel-tubed and thermoplastic-hosed umbilical product(s).
### Technip's SPU market share by type (2000-3Q11 3300km)

- **Thermoplastic**: 39%
- **Steel**: 61%

Source: Quest Offshore Resources, Inc

### Companies in the subsea market with public equity (alphabetical by company name)

<table>
<thead>
<tr>
<th>Company</th>
<th>Blomberg ticker</th>
<th>Country of primary exchange</th>
<th>Corporate office</th>
<th>Market cap (US$bn)</th>
<th>Subsea equipment products</th>
<th>Other businesses</th>
<th>Subsea business mix note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aker Solutions</td>
<td>AKSO NO</td>
<td>Norway</td>
<td>Fornebu, NORWAY</td>
<td>2.9</td>
<td>Trees, production systems, umbilicals and controls</td>
<td>Engineering, procurement and construction contractor, drilling equipment, surface trees...</td>
<td>~27% of revenues from subsea products</td>
</tr>
<tr>
<td>Baker Hughes</td>
<td>BHI</td>
<td>USA</td>
<td>Houston, USA</td>
<td>22.4</td>
<td>Pumps</td>
<td>Diversified oil services</td>
<td>na</td>
</tr>
<tr>
<td>Cameron International</td>
<td>CAM</td>
<td>USA</td>
<td>Houston, USA</td>
<td>12.1</td>
<td>Trees, production systems, subsea wellheads and controls, separation systems, pumps</td>
<td>Blowout preventers, valves, surface wellheads</td>
<td>~25% of revenues from subsea products; ~28% of operating income from subsea</td>
</tr>
<tr>
<td>Dril-Quip</td>
<td>DRQ</td>
<td>USA</td>
<td>Houston, USA</td>
<td>2.6</td>
<td>Trees, production systems, subsea wellheads and controls</td>
<td>Surface wellheads, surface trees, drilling risers, wellhead connectors</td>
<td>~70% of revenues from subsea equipment sales</td>
</tr>
<tr>
<td>FMC Technologies</td>
<td>FTI</td>
<td>USA</td>
<td>Houston, USA</td>
<td>12.5</td>
<td>Trees, production systems, subsea wellheads and controls, processing pumps, separation systems</td>
<td>Valves, meters, surface wellheads</td>
<td>~65% of revenues from subsea products; ~67% of operating income from subsea</td>
</tr>
<tr>
<td>Fugro</td>
<td>FUR NA</td>
<td>Netherlands</td>
<td>Leidschendam, NETHERLANDS</td>
<td>4.7</td>
<td>Remotely operated vehicle (ROV) operator</td>
<td>Seismic acquisition and processing, laboratory testing</td>
<td>Subsea services was 18% of backlog at 30 June 2011</td>
</tr>
<tr>
<td>GE</td>
<td>GE</td>
<td>USA</td>
<td>Fairfield, USA</td>
<td>189.5</td>
<td>Trees, production systems, subsea wellheads, controls, risers and flowlines, subsea pumps, separation systems</td>
<td>Appliances, aviation, electrical distribution, middle market financing...</td>
<td>na</td>
</tr>
<tr>
<td>Halliburton</td>
<td>HAL</td>
<td>USA</td>
<td>Houston, USA</td>
<td>32.2</td>
<td>Safety systems</td>
<td>Diversified oil services</td>
<td>na</td>
</tr>
<tr>
<td>John Wood Group PLC</td>
<td>WG/ LN</td>
<td>UK</td>
<td>Aberdeen, UK</td>
<td>3.7</td>
<td>Umbilicals, risers and flowlines</td>
<td>Engineering, procurement and construction (EPC) management, operations and maintenance</td>
<td>na</td>
</tr>
<tr>
<td>NKT</td>
<td>NKT DC</td>
<td>Denmark</td>
<td>Brondby, DENMARK</td>
<td>0.8</td>
<td>Risers and flowlines</td>
<td>Power cables, cleaning equipment, fiber optics</td>
<td>~15% of operational Ebitda expected in 2011 from risers and flowlines</td>
</tr>
<tr>
<td>Oceaneering</td>
<td>OII</td>
<td>USA</td>
<td>Houston, USA</td>
<td>5.0</td>
<td>Remotely operated vehicle (ROV) operator, umbilicals and controls</td>
<td>Testing/inspection services and robotic services</td>
<td>~77% of revenues from ROVs and subsea products and projects</td>
</tr>
<tr>
<td>Oil States International</td>
<td>OIS</td>
<td>USA</td>
<td>Houston, USA</td>
<td>3.9</td>
<td>Risers and subsea pipeline repair equipment</td>
<td>Accommodations, tubular goods</td>
<td>Expect offshore products to be 16% of revenues in 2011</td>
</tr>
<tr>
<td>Saipem</td>
<td>SPM IM</td>
<td>Italy</td>
<td>Milan, ITALY</td>
<td>18.7</td>
<td>Remotely operated vehicle (ROV) operator</td>
<td>Offshore and onshore drilling, EPC</td>
<td>na</td>
</tr>
<tr>
<td>Schlumberger</td>
<td>SLB</td>
<td>USA</td>
<td>Paris, FRANCE</td>
<td>91.0</td>
<td>Subsea pumps and meters</td>
<td>Diversified oil services</td>
<td>na</td>
</tr>
<tr>
<td>Subsea 7</td>
<td>SUBC NO</td>
<td>London</td>
<td>London, UK</td>
<td>6.5</td>
<td>Remotely operated vehicle (ROV) operator, risers and flowlines</td>
<td>Engineering, procurement, installation and commissioning (EPC) project delivery for subsea field developments</td>
<td>~52% of revenues in 2010 from SURF, including EPC work</td>
</tr>
<tr>
<td>Technip</td>
<td>TEC FP</td>
<td>France</td>
<td>Paris, FRANCE</td>
<td>10.4</td>
<td>Umbilicals, risers and flowlines</td>
<td>Floating platforms; Engineering, procurement and construction (EPC) management, operations and maintenance</td>
<td>44% of 3Q11 revenues from subsea; ~22% of backlog from deepwater work &gt;1,000 meters</td>
</tr>
<tr>
<td>Weatherford</td>
<td>WFT</td>
<td>USA</td>
<td>Geneva, SWITZERLAND</td>
<td>11.7</td>
<td>Control systems</td>
<td>Diversified oil services</td>
<td>na</td>
</tr>
</tbody>
</table>

Note: Market capitalization in US dollars from Bloomberg as of 30 December 2011. Product list is a sample of products; not all-encompassing.

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Technip captures a larger share of steel-tube umbilical sales
Appendix 2: Development stages

Every offshore oilfield development project goes through a “life-cycle.” This plan involves deciding what equipment and infrastructure an operator will need to produce the wells and transport resources back to shore, and where to place this equipment to optimize production.

The typical field development plan moves through predetermined stages – the terminology may vary from operator to operator but the steps are generally the same. These six stages outline the main processes each offshore oil and natural-gas development goes through in order to become a producing asset.

### Typical development timeline for offshore developments

<table>
<thead>
<tr>
<th>Appraise &amp; Define</th>
<th>Concept Selection</th>
<th>Project Sanction</th>
<th>FEED &amp; Detailed Engineering</th>
<th>Execute</th>
<th>Operate</th>
</tr>
</thead>
</table>

Source: Quest Offshore Resources, Inc

Today, we believe the typical life-cycle of an oilfield is about seven years from the first “appraise and define” phase to initial production in the “execute” phase. During an oil company’s “execute” phase, the wells for the field are completed and finished with control modules and subsea trees. The wells are then tied together via pipelines and powered by the subsea umbilicals. Pipelines carry the produced product to shore on the ocean floor, or risers carry the production horizontally topside to an offshore fixed or floating platform production facility.

### Stage one: appraise and define

This is the assessment, exploration, appraisal and definition stage of a project in which field operators engage in the evaluation and appraisal of potential oil and natural-gas targets.

#### Seismic

This part of the project includes conducting seismic surveys to locate promising areas. The first stage to develop an offshore oil and natural-gas field is finding out where the resources are. To do this, the industry relies on specialized seismic contractors who provide imaging and data of the geologic formations below the seafloor.

The seismic images and data captured by these contractors provide critical information to properly trained eyes. According to the physical composition of these formations, geologists, geoscientists and other experts will then determine the areas in which oil and natural gas may be present.

If a potential oil or natural-gas target looks promising, the oil company that owns the offshore lease will create an exploration plan, which includes the scheduling of exploration wells. If the operator(s) decides to move forward to drill an exploration well, the operator(s) will secure the services an offshore drilling rig through a new contract or extend an existing contract. Offshore drilling contractors have been vital to the industry since the first underwater well was drilled beneath a lake in Louisiana in the 1910s.
Exploration well
Exploration wells must be drilled to further determine the size and extent of the potential field. Direct physical evaluation of formations, or reservoirs, is accomplished by drilling exploration wells. In general terms, an exploration well is viewed as a “sample” production well. This exploration well will allow companies to determine: 1) if oil or natural gas is present; 2) the quality of the product; and 3) the potential size of the formation.

Field definition
The “define” stage is very important, as it sets the foundation for if and how a field is developed. The operating company uses data and information collected during exploration and appraisal drilling to define the layout and physical composition of the oil and natural-gas resources in place.

Flow tests during exploration drilling are very important because they determine how easily oil and natural gas flows throughout the reservoir. Operators consider the estimated recoverable amount of resource in place and apply financial models to determine the commercial viability of the field. If the field is deemed economic, the operator(s) make further development plans in the next “concept selection” phase of field development.

Stage two: concept selection
During the “concept selection” stage, the operating oil company and its partners work together to develop an optimal plan for developing an offshore field or well. During this stage, the companies will consider different concepts for how to best develop the field in a manner that adheres to any and all regulations and is efficiently profitable to all parties. Often included in this stage are discussions about whether or not the field is large enough to require its own in-field host/processing facility (stand-alone, fixed platform or floating platform). This stage is also where the operator(s) will decide how many wells to drill offshore, optimize well placement, determine the pipeline needs and designs and determine the quantity and location of other equipment to be placed on the seafloor.

Stage three: project sanction
Once professionals in charge of the field propose the concept for development, typically an executive committee from varied disciplines will decide whether or not to sanction the field. An important consideration for the operator(s) when they evaluate sanctioning a project (given they feel they have received a suitable development plan) is the potential profitability of the field.

Importantly, the companies involved in developing and producing the field must feel comfortable that they will receive a company-specific return on their capital investment. A field may cost as much as US$10bn, and make take several years to fully develop. The decision to sanction a project is a crucial decision. This decision and must consider various scenarios to ensure that the owners in a project remain financially healthy and are able to maintain a long-term competitive position.

Stage four: FEED and detailed engineering
Once sanctioned, the project moves into the engineering and design phase. During this phase, the oil companies, their suppliers and third-party support organizations work together to design and manufacture the highly technical pieces of equipment, as well as determine the installation methods. Engineers spend many hours pouring over technical specifications and designs to ensure
that the minute details of each piece of equipment are built exactly to specification. As such, this stage of work employs the use of many highly trained and highly skilled engineers. This process generally takes more than a year to complete but the timing can vary depending on the size of the project.

**Stage five: execute**

Within the execute phase, operator(s) oversee the installation of the customized and technically sophisticated subsea equipment that will enable the production of oil and/or natural gas from a field. The operator(s) complete and finish wells with the control modules (ie, subsea trees). The operator(s) then tie together the wells with pipelines, powering the control modules/trees with subsea cables or umbilicals. Pipelines then carry the produced product either straight back to shore or to an offshore fixed or floating platform production facility.

Within the Execute Phase, operators will conduct the development drilling, procure materials and equipment, and fabricate subsea facilities.

**Development drilling**

Development drilling is when the operator will use offshore drilling contractors and oilfield services companies to drill and complete the wells targeted for production in the field. This component of a field’s development, together with the exploration drilling, regularly accounts for roughly 55-60 percent of a field’s overall cost to the operator.

**Materials and equipment procurement**

Simultaneous to the beginning of development drilling (and often even before development drilling begins), the operator will begin to secure contractors for all of the equipment needed for the subsea production facilities. During these activities, oil companies rely on supply-chain management professionals to negotiate mutually beneficial terms for all parties involved, while ensuring that the project schedule is maintained.

**Facility fabrication**

Often, the most critical component to be fabricated is the host facility for the field (the offshore or onshore production storage facility). These units represent a large portion of costs to develop an offshore field, and can take upwards of three years to complete, depending on the size of the unit. Once the contractor completes the fabrication of the facility, the hull and topsides are "mated" either just offshore from the fabrication yard, or the topsides are transported to the field and lifted onto the hull for final commissioning in preparation for production.

**Fabrication of subsea systems**

An operator will use the previously developed designs and plans to solicit bids and eventually secure a contracts for the fabrication and delivery of the subsea equipment that will control the production of each well. The contract for the average control system (subsea tree plus control package) is often a large part of the total SURF package and the cost can average US$9-15m.

Once fabricated and delivered, the oil company will employ the use of the drilling rig working on the development wells to install the subsea system on each completed well. The control systems are connected and controlled at the surface by the use of subsea umbilicals.
**SURF fabrication: subsea umbilicals**

The operator will use subsea umbilicals to ensure proper control and powering of the well. These units are essentially long underwater cables used to provide power (electric or hydraulic) to subsea systems, as well as providing essential fluids and chemicals to maintain production.

Similar to subsea trees and control systems, the umbilical is a highly engineered piece of equipment that requires a fair amount of engineering work to safely employ on a field. The costs for this piece of equipment can be generally categorized as: Engineering/Design, Raw Materials, Fabrication, and Delivery & Installation.

Once the umbilical manufacturing contract has been placed, the field operator will contract for the installation of this equipment using a dedicated installation vessel or boat. While costs for these boats can reach rather large numbers of a “cost-per-day” basis, it is important to note that the industry’s highly skilled contractors have created large efficiencies in the installation of these cables, significantly reducing the total time required for installation.

**SURF fabrication: risers and flowlines (pipes)**

While subsea umbilicals are highly specialized units, offshore pipelines (and pipelines in general) are essentially a global commodity. Even though there are added complexities with the fabrication of subsea pipelines, generally speaking, a pipeline is a pipeline. Moreover, steel is traded globally across a multitude of industries.

Like the subsea umbilical, the installation of pipelines relies on the industry’s fleet of offshore installation vessels to complete these activities. However, a key difference for these pieces of equipment is seen in the type of boat needed to perform the job.

Once the flowlines and risers are installed, the lines are tested to ensure there was no damage during installation. Provided that these tests produce positive results, the transportation system of the oilfield is ready for use. While conceptually fairly straightforward, the risers and flowlines of an oilfield are some of the most critical components that employ a high degree of technical complexity and subsequently high capital cost.

**Stage six: operate**

Once a field starts producing oil and/or natural gas, the owners of the field will “operate” the field to maintain safe and efficient production. Operating the deepwater field includes maintaining a suitable flow of resources through the infrastructure and systems installed during the “execute” phase. The operating phase must ensure that production continues at a level that ensures a financial return to the operators.

Operating activities range from continuously supplying food and fuel to the platform, repairing damage caused by the wear and tear associated with full time exposure to the elements, performing routine maintenance to ensure continued safe operations and ensuring safe transportation of produced fluids.

All these activities require continued employment of not only a large crew on the production platform itself, but also require support staff onshore. The operating company requires onshore administrative, management, and engineering support. Onshore suppliers must provide the necessary equipment and supplies. Boats and helicopters will transfer crew and supplies back and forth. Wells must be monitored and worked over when necessary.
Appendix 3: Quest research approach

The illustration below is a simplified overview of Quest Offshore’s Research and Data Collection process, as well as a model of how Quest’s consultancy practice works in conjunction with this process. In brief, Quest utilizes a variety of data and/or information sources when acquiring and validating data, according to the following classifications:

- **“Project-Level Data”** refers to that data which is specific to offshore field development projects through their lifecycle
- **“Primary Sources”** refers to Quest’s contacts within the entire industry global supply chain
- **“Secondary Sources”** refers to any publically available information (financial reports, press releases, technical papers, presentations, etc)
- **“Tertiary Research”** refers to data and/or information required, usually for client-directed consulting projects

While the model provided below does not detail every activity undertaken by Quest during its daily acquisition of data, it does outline the fundamental process followed to ensure data is timely and accurate. For the purposes of this study, Quest has relied primarily on its project-level data, primary sources and tertiary research through the scope of the project. Moreover, Quest was able to utilize the Quest Enhanced Deepwater Development Database to quantitatively analyze the historical and potentially projected projects where the subsea technologies of interest have been or will be deployed in future.

**Background/project overview**

To adequately address the goal of this study, Quest has divided the execution of research into a few key stages. First, Quest sought to quantitatively assess the historical baseline of demand and implementation for subsea hardware, associated equipment and technologies across the entire subsea segment of the offshore oil and gas industry. This was primarily accomplished by utilizing Quest’s proprietary Enhanced Deepwater Development Database (incorporating Quest Subsea Database), which serves as a comprehensive industry-wide record of historical and future deepwater field development solutions. The granular data contained in the aforementioned database allowed for the rapid synthesis and analysis of this data providing for accurate and timely quantitative analysis.

Subsequently, Quest engages in ongoing, focused research to determine the qualitative aspects of the subsea industry including operator demand profiles and well as global supply chain drivers and relationships. This included obtaining an understanding of each company’s commitment to subsea technology research and development—owners (IOCs, NOCs and independents) as well as key suppliers, OEMs and other vendors.

Once the following information was compiled, Quest focused on the further synthesis of the data and information to produce a complete study that encompasses all facets of the subsea industry include the known areas of key focus by operators and subsea technology providers. The contents of this CLSA U Blue Book addresses these key focus areas providing key insights into the current and future state of subsea technology globally.
**Quest research approach**

- **Project-Level Data**
- **Primary Sources**
- **Other investors**
- **Secondary Sources**

**Quest Data Validation Process**

**Quest Offshore Deepwater Development Database**

**Market Data & Analysis**

**Quest Supplemental Databases/Offline Data Records**

**Client-Directed Consulting**

*Source: Quest*

**Subsea equipment**

*Source: FMC Technologies*
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12/01/2012