

**SLOR™ PRODUCTION SYSTEM
MAKING IT EASY FOR THE PLATFORM**

by

Frank Lim & Dave Walters - 2H Offshore

Paper Abstract

Riser weight increases with water depth. It is a simple fact. Supporting the risers, tensioning them to control their response, or optimising the platform motions in order to be “riser-friendly” is often one of the most challenging aspects of converting an old floater for use as a deepwater production or drilling platform. A new build platform will address these issues as part of its design for a particular application, but it will soon have payload and water depth limitations when used generically for multiple applications.

A solution has been proposed, with a focus on the important issues of well access and riser design, which will remove the payload and water depth constraints from the platform, be it a new design or a conversion.

Utilising direct access subsea tress and free standing single line offset risers (SLOR), a semi-submersible equipped with production and drilling facilities not only challenges a dry tree platform solution, such as TLP and spar, it offers many additional safety and operational advantages. The benefit of this SLOR production system is best realised in the very deep water depths, when the design of top tensioned dry tree risers and their impact on the platform become even more imposing and costly.

This paper compares the merits of the SLOR production system against the more familiar dry tree production systems, and points to ways of implementing this solution in the Asia Pacific market.

INTRODUCTION

Deepwater oil and gas fields are currently developed using wet (subsea) trees or dry (surface) trees, or a combination of both. Once the reservoir characteristics have been determined, the evaluation of development options for a new field is usually focussed around the type of floating production vessel required to develop the field, whilst the well and riser systems are often ignored until the development scenario has been selected.

Dry tree units provide direct access to the wells for workover and improved recovery but require motion optimised hulls to accommodate the riser systems and are considered limiting with respect to water depth and development flexibility. Although widely used for developments in shallow to medium water depth, dry tree units are not considered the optimum way to develop the deep and ultra deep opportunities, despite the industry's preference to extrapolate field proven solutions.

Subsea developments are suitable for widespread reservoir structures. They provide a degree of vessel and field expansion flexibility with simplified riser interfaces, but at the expense of high drilling and workover costs.

Due to the increasing costs of developing fields in deeper waters, the focus of development solutions should be placed on key 'enabling' technologies such as the well and riser systems, and in developing floating production systems which are safe, cost effective, flexible enough to accommodate changes, and capable of being built locally. This is particularly applicable in the upcoming oil and gas plays of the world such as South East Asia where, being remote to the current deepwater activities elsewhere in the world, construction vessel availability is limited and mobilisation costly. The ability to construct or convert the vessel locally will boost employment and the economy of the developing country.

DEEPWATER DEVELOPMENT DRIVERS

The primary design driver is always cost. In deep water, large oil and gas reserves are required for economic recovery of the hydrocarbons. In water depths above 5000ft, reserves lower than 100MMBOE are generally considered marginal if a 'stand alone' floating production system is required. This implies that deep and ultra deep water developments will include a large number of wells to recover the large reserves. The factors affecting the costs of a deep water development are complicated and extensive but the key design drivers include:

- Minimise drilling CAPEX – is it possible to drill from the FPS?
- Minimise workover cost (OPEX) – can the wells be maintained from the FPS?
- Minimise floating production vessel costs – is a motion optimised vessel required?
- Minimise offshore construction
- System flexibility for future wells, without risk weighted pre-investment
- Simplified interfaces to reduce schedule to first oil
- Flexibility to potentially accommodate an Early Production System (EPS)
- Riser system impacts on host vessel requirements.
- Flow assurance management (thermal performance and well productivity)

The use of existing dry tree and wet tree solutions each tackles some of these design drivers but not all can be accommodated. This is discussed further in the following section.

EXISTING SOLUTIONS

A great number of dry tree Spar and TLP systems are currently in production with several planned in the near future, Figure 1. It is recognised that not all spars and TLPs are dry tree units, as a number of all-subsea developments are using spar and TLP to locate their processing facilities.

The main benefit provided by the dry tree arrangement is direct access to surface trees for production control and vertical well access for workover, mimicking the functionality of a bottom founded shallow water platform system. In addition the minimal flow length from reservoir to facility assists with flow assurance requirements, preventing wax and hydrate conditions commonly seen as a design challenge for subsea development. For developments with high well count or deep and complex reservoirs, dry tree units equipped with a drilling rig reduce drilling costs by avoiding the need for a high cost mobile drilling unit. For smaller well counts, pre-drilling and pull-over drilling can be considered and this is often more economical than providing a full drilling spread.

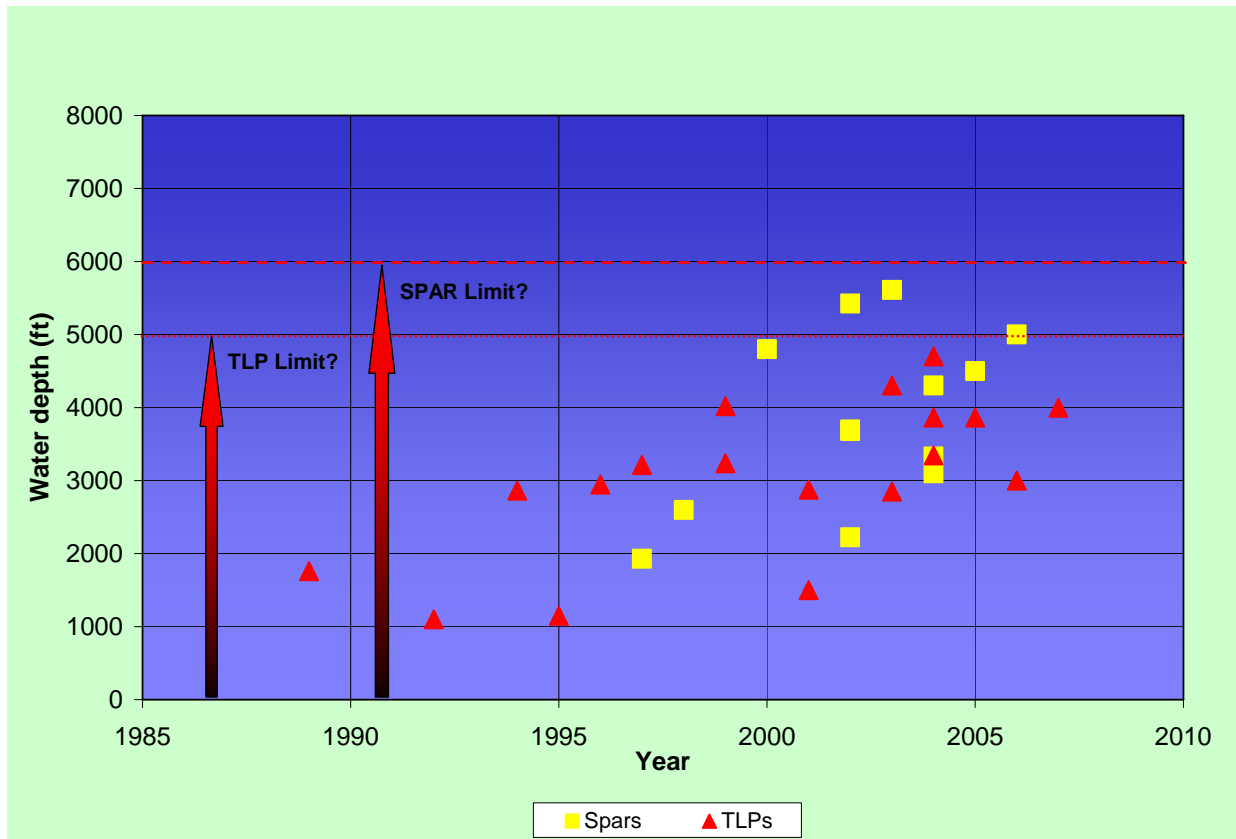


Figure 1 – Summary of Worldwide Dry Tree Units

The efficient drilling and workover benefit of the dry tree system is offset by the following disadvantages:

- Limited host facility options (spar or TLP)
- Proprietary vessel designs
- Water depth limitations
- Complex riser/vessel interfaces
- Offshore construction requirements
- Limited expansion flexibility
- High capital costs

The spar and TLP both have the objective of providing a stable platform with minimum motions, particularly heave, to support the production risers. The spar achieves this by optimising hydrodynamic loading with a deep draught and the TLP by tethering to the seabed. Both concepts provide good solutions for what are now considered medium water depths 1,800-4,000ft, but they are considered fundamentally troublesome and impractical for deep and ultra deep water applications.

The problem with the TLP is associated with the tether design and the practical ability to provide adequate levels of axial stiffness as water depth increases. Thus TLPs have a practical depth limitation of around 5,000ft, although it is understood that development work is being undertaken to attempt to extend the water depth.

The spar water depth limitation is not a function of the vessel configuration but that of increased riser weight in deepwater, particularly for dual casing systems. Whilst the need for the second casing is the subject of discussions, the argument for dual casings is stronger for greater water depths and higher pressure reservoirs. Large tension requirements result in the need for large aircan buoyancy, which can be achieved by either increasing the length or diameter of the can. The aircan length is limited to approximately 230ft from handling and installation considerations and is to remain within the hull hard tank to reduce hydrodynamic loading. An increase in aircan diameter has the impact of increasing the well bay spacing, potentially leading to a larger diameter hull with higher fabrication costs, particularly for large development with 12-16 wells.

The alternative is to utilise hydro-pneumatic tensioners, as has been the case on the recent spars, which simplifies the hull/riser interface but has the following implications:

- Increased vessel payload and associated increase in hard tank capacity;
- Large stroke tensioners required due to hull offset which increases with water depth;
- Hydrodynamic response affected due to lowering of vessel heave natural period from riser tensioner stiffness;
- Increased riser fatigue damage from tension fluctuations.

It is clear that there is no easy solution to providing the necessary support to heavy top tensioned spar risers in ultra deep water.

Of particular hindrance to the spar in the Asian market is the requirement for extensive offshore construction and the need for specialist heavy lift vessels required for aircan and topsides installation. The availability of such vessels is focussed within the 'golden triangle' of GOM, West Africa and Brazil, indicating that high cost mobilisation is required to Asia in order to install a spar facility.

A further limitation of both the spar and TLP is their inability to expand the facility to accommodate additional risers in the event of favourable reservoirs being uncovered during production. For the spar, the facilities team needs to fully understand the extent of the reservoir in order to design the spar with sufficient well slots to accommodate the required number of risers. Uncertainty in reserves leads to commercial risks in the pre-investment of additional well slots that may not be required, which ultimately impacts the overall size of the hull and subsequently hull fabrication costs. For the TLP, payload considerations must be taken into account in order that the hull is fabricated with sufficient buoyancy to accommodate the riser loads. Again, over estimation of the number of risers to support is expensive if never used to full capacity, and limiting for future tiebacks if insufficient payload capacity is provided.

Unlike dry tree units, subsea developments have greater flexibility with respect to hull selection. It provides a solution with the ability to develop reservoirs in deepwater environments. Figure 2 shows the trend of deepwater developments using subsea trees and it can clearly be seen that water depth is not a major limiting factor.

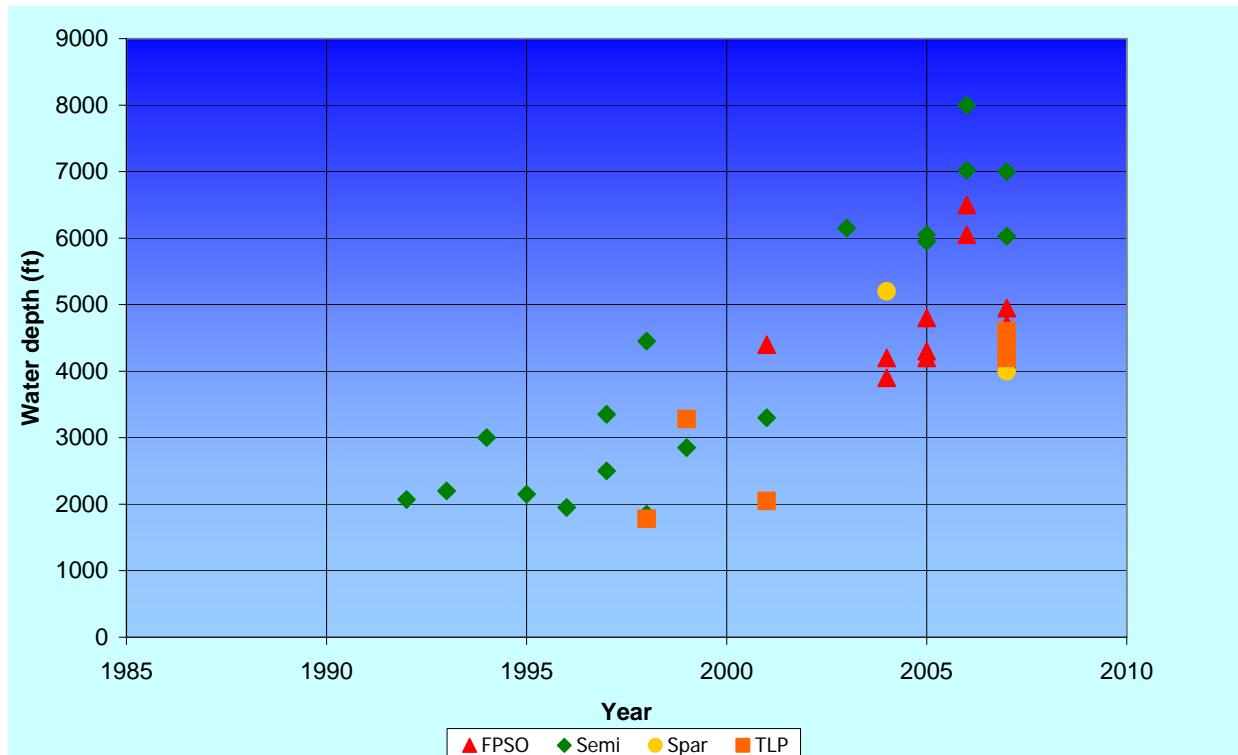


Figure 2 – Summary of Worldwide Subsea Developments

Despite the drawbacks associated with dry tree system in ultra deep water, the benefits of efficient drilling and OPEX cost are paramount. Subsea field developments tend to offer economic improvement in areas such as vessel requirements, reduced offshore construction and development flexibility, but lack the efficient drilling and completion capability. It is interesting to note that the benefits and limitations of subsea and dry tree developments are polar opposites. This is illustrated in Table 1.

Feature	Dry Tree Development	Subsea Development
Drilling Cost	From facility	Requires MODU
OPEX Costs	From facility	Requires MODU
Facilities CAPEX Cost	High cost hull	Choose least cost hull
Offshore Construction	Heavy lift requirements	Depends on riser system
Development Flexibility	Restricted due to hull form	Minimal vessel impact
Riser/Vessel Interfaces	Complex interaction	Simpler interaction
Vessel Flexibility	Restricted to Spar or TLP	Full range
Shut in location	In well bay close to people	Seabed Isolation and Offset
Flow Assurance	Shortest Flow Path	Potentially long tie flowlines

Table 1 – Dry Tree and Wet Tree Pros and Cons for Deepwater Developments

2H Offshore have been involved in the design of riser systems for many of the deepwater field developments in West Africa, Gulf of Mexico (GoM), Brazil, Indonesia and the North Sea. The experience gained from designing complex riser systems heavily influenced by the response of the floating production vessel, has enabled the company to develop riser systems with simpler interfaces.

It is recognised that both dry tree and subsea tree development concepts have drawbacks, and this in turn has spawned the conception of a new field development solution, known as SLOR™ Production System, which focuses on risers and well systems, addressing many of the fundamental deepwater field development drivers described previously.

ALTERNATIVE DEEPWATER PRODUCTION SOLUTION

The alternative field development solution, termed the SLOR™ Production System (or SPS in short), is presented herein and shown in Figure 3.

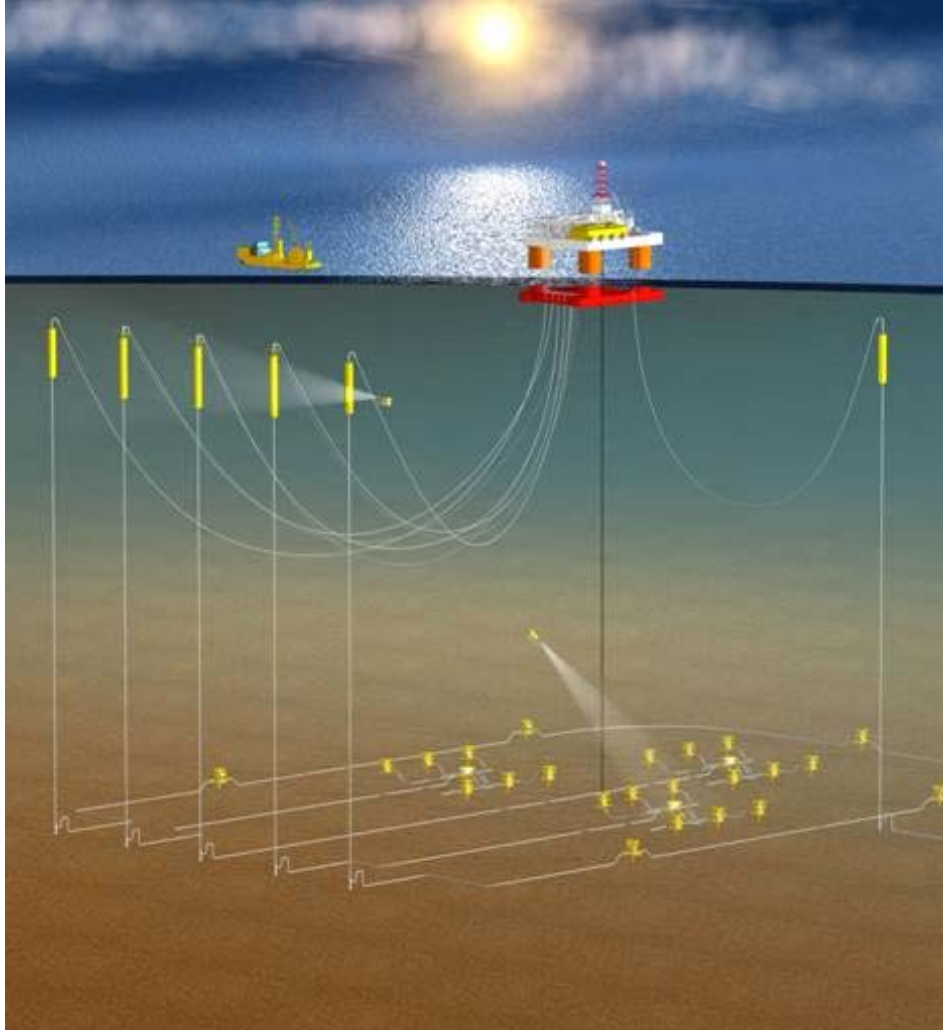


Figure 3 – SLOR™ Production System Arrangement

The SPS is a unique field development solution for deepwater that has a focus on the important issues of well systems and risers. This is unlike conventional field developments that are driven by naval architecture considerations, particularly for dry tree units. This solution considers the pros and cons, then combines the benefits of dry tree and subsea tree systems given in Table 1, and provides the following additional advantages:

- It is illogical to tie back heavy dry tree risers in deepwater;
- Long flowlines on cold seabed are not process flow friendly;
- Maintain direct well access for efficient drilling and workover;
- Minimise riser numbers and simplify their design interfaces;
- Simplify execution by providing contractual flexibility;
- Reduce offshore construction requirements;
- Eliminate requirement for heavy optimised platform such as spar or TLP;
- Take advantage of low cost and reliable subsea trees that provides subsea isolation;
- Provide development flexibility for future wells without pre-investment.

The SPS uses subsea wellheads located below a permanently moored floating production platform. An important feature of this concept is that the riser system is designed to exhibit a quasi static response, decoupled from the vessel motions. As a result the motions of the vessel do not have to be highly optimised leading the operator to select an less expensive production facility that is cheap to construct without having to be overly concerned about the motion response. This may be either a barge for application in a mild Indonesian environment or a semi-submersible for Brazil and the Gulf of Mexico, neither of which require extensive amounts of offshore constructions like Spars and TLPs.

The wells are drilled using a high pressure drilling riser and surface BOP in the same manner as currently conducted from a conventional dry tree platform. The surface BOP provides efficient drilling through the reduction in trip time and minimum down time. The wells are completed with 'horizontal' or 'drill through' trees that locate the tubing hanger in the tree spool. Importantly this arrangement facilitates direct vertical access through the drilling riser or a smaller diameter workover riser into the wellbore, without the requirement of setting plugs and removing the tree.

The subsea wells are grouped in clusters and may be situated on or off a manifold that allows up to 5 wells to be commingled. This allows the number of risers to be reduced by up to 75%. Each manifold is connected via a rigid seabed line to the base of a free-standing riser. The riser may be either a single pipe (Single Line Offset Riser – SLOR™) or a pipe in pipe design (Concentric Offset Riser - COR™) that provides additional insulation and allows riser base gas lift or active heating through the annulus. These risers can be either welded or threaded construction and are tensioned by an upper aircan located at 50-150m below the surface depending on the environmental conditions.

Each freestanding riser is connected to the production platform by a shallow water flexible jumper. The risers, including aircan and flexible jumpers, can be quickly installed from a drilling platform, construction vessel or from the production platform itself, giving a high degree of installation flexibility. In addition freestanding risers can be used for export, enabling a fast development installation schedule by pre-installing all risers prior to arrival of the host facility. The SLORs and CORs have been installed in West Africa for the ExxonMobil, Kizomba A and B field developments and are planned for installation on Petrobras P52 field in 6,000ft water depth with the function of exporting oil to shore.

The flexible jumper between the riser and platform offers two key advantages: firstly they can accommodate large platform motions allowing lower cost non-motion optimised platforms to be considered, and secondly they can be connected to the platform at a location to best suit the platform layout. Normally this would be away from the central drilling moonpool area, providing segregation of drilling and production activities.

The reduction in riser numbers is critical, particularly as water depth increases, in the contribution to cost reduction of the production system. It is important to note that some 80% of the dry tree system hardware is sensitive to water depth, as opposed to only about 20% for the SPS arrangement. Consequently, as water depth increases the cost difference between the dry tree and SPS well system will increase, with SPS showing to be much less expensive.

It should be noted that the SPS is neither a classic subsea system nor a dry tree system but it offers the best features of each and avoids many of the disadvantages. The arrangement is suited to a wide range of field development types and environments. The SPS is particularly suited to developments where reserves are uncertain as the system configuration allows the addition of future wells without pre-investment of additional wellbay space or platform buoyancy requirements. SPS is effectively a 'self contained' system that can develop the reservoir in a phased execution without the requirement for an additional installation vessel to be mobilised to install risers or flowlines.

APPLICABILITY TO ASIA MARKET

A successful field development can start with an arrangement that minimizes CAPEX through eliminating the use of high cost installation and construction vessels. This is particularly important in Asia whereby the mobilization of large capacity derrick barge will have a significant economic impact on the development. The SPS field development solution is designed around the ability to use the lowest cost production facilities that do not require heavy lift vessels to install topsides, and riser systems that can be installed using vessels readily available in the Asian market, or even from the drilling rig on the production facility itself.

SPS is configured with a riser system to operate without a highly specified heave optimised vessel. A vessel of convenience can therefore be converted to serve as the production platform, as long as it has the capacity to carry the drilling rig and suitable processing facilities on the topsides. A conversion offers improved schedule to first oil and is significantly less costly than a new build, and more likely to be within the capability of local shipyards. However, as the SPS platform is re-usable and, unlike a dry tree unit, is independent of well count, investment on a new build vessel may be justified if longer term multi-field applications are envisaged. Even then, the type of vessel to build is entirely the operator's choice, and it can be non-proprietary and chosen to suit the local capabilities. A locally built and commissioned production platform will have only a short distance to travel to the field thereby shortening the lead time to first oil.

Furthermore, the SLOR and COR systems utilise riser components, such as large diameter steel buoyancy cans and suction anchors, that are well suited for local fabrication. Placing the orders with local fabricators will create business and employment opportunities for the regional economy.

Finally, SPS lends itself to be used as an early production system. The ability to increase the well count and install additional risers at minimal costs will prove to be a very flexible development tool to initiate production from a large number of fields. This will significantly cut down the normal time spent evaluating and optimising development options for sanction, and lead to earlier return of oil revenues which must help meet the economic targets for the emerging oil producing countries.

CONCLUSIONS

It can be seen that conventional dry tree solutions with the use of spar and TLP technology is proving to be ‘hamstrung’ by increasing water depths and the trend is observed that operators are defaulting to subsea developments for field developments in excess of 6,000ft water depth, and accepting the higher drilling and workover costs associated with subsea developments.

The SPS concept has been developed with a riser and well systems focus with intent on taking the beneficial features from both subsea and dry tree developments, whilst providing flexibility to enable efficient contract strategy’s to be implemented.

Feature	SLOR™ Production System	
Drilling Cost	From facility	
OPEX Costs	From facility	
Facilities CAPEX Cost		Choose least cost hull
Offshore Construction		Minimal required
Development Flexibility		Minimal vessel impact
Riser/Vessel Interfaces		Simpler interaction
Vessel Flexibility		Full range
Shut in location		Seabed Isolation and Offset
Flow Assurance	Shortest Flow Path	

Table 2 – Summary of SPS Features

Compared to a dry tree system the SPS arrangement offers improved technical performance, higher levels of safety, reduced interface complexity, improved development flexibility and lower cost. It also enables the step into deep and ultra deep water developments to be made with confidence, using proven components and technologies.

Finally, the SPS solution provides opportunities for Asia’s emerging deep water oil producing countries to convert or build the production platforms in their own shipyards, benefiting their own economies; to become less reliant on mobilisation of large offshore construction vessels, saving significant installation costs and schedule; and to have early production systems that can later be expanded to be life-of-field facilities, bringing faster revenue returns and achieving production targets. In summary, a logical solution to any aspiring deepwater operators in the region.