OPPORTUNITIES FOR OFFSHORE VESSELS UPGRADING AND CONVERSION

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Energy market conditions change rapidly, with corresponding new demand for equipment, floating units and support vessels. Newbuilding is a substantial investment and often takes (too) much time to obtain maximum benefit from an emerging opportunity. Upgrading or conversion of an existing unit can be a good alternative. There are eight different hull types to choose from for floating offshore units. The most common vessel type is the ship-shaped monohull.

Within the large pool of existing merchant and offshore vessels, both new and ageing, there are many suitable candidates for upgrades and conversions. Such a new lease of life expands their operational and economical portfolio and serves the offshore industry in reaching spectacular advances in transport, construction and installation performance.

When upgrading or converting existing units multiple tiers of capability increase are distinguished. Each tier brings increasing complexity, risks and re-building costs. Options range from lifetime extension and modernisation of an older vessel, temporary conversion, capacity upgrade, adding functions, changing the present function, or ultimately the complete transformation of an older merchant cargo vessel into a brand new offshore unit.

Major vessel conversions can be competitive with newbuilding options, provided that such a complex conversion project is prepared and managed well. Some remarkable examples of capacity upgrades, double conversions and complete vessel makeovers are presented.

Keywords: Offshore, Support, Vessel, Upgrade, Conversion, Newbuilding.

NOMENCLATURE

ASV	Accommodation and Support Vessel
A&R	Abandonment and Recovery
BWTS	Ballast Water Treatment System
CAPEX	Capital Expenditure
DDCV	Deep Draft Caisson Vessel
DP	Dynamic Positioning
E&P	Exploration and Production
FLNG	Floating Liquefied Natural Gas
FPSO	Floating Production Storage Offloading
FPU	Floating Production Unit

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FSO	Floating Storage Offloading
FSRU	Floating Storage Re-gasification Unit
HSE	Health Safety Environment
IMR	Inspection Maintenance Repair
LNG	Liquefied Natural Gas
LSA	Life Saving Appliances
MCV	Modular Capture Vessel
MDMV	Marine Diamond Mining Vessel
OPEX	Operational Expenditure
O&G	Oil and Gas
PSV	Platform Supply Vessel
OSV	Offshore Support Vessel
ROV	Remotely Operated Vehicle
SCR	Steel Catenary Riser
SURF	Subsea Umbilicals Risers Flowlines
TLP	Tension Leg Platform
VDL	Variable Deck Load
WFSV	Wind Farm Support Vessel
WSV	Well Stimulation Vessel
WTIV	Wind Turbine Installation Vessel

1. INTRODUCTION

Employment for offshore vessels depends very much on fluctuations in offshore exploration, production and maintenance activity levels. Evolving market opportunities in the offshore oil & gas and wind industries create options for vessel operators to adapt their assets in various ways. They may add or increase drilling, production, heavy lifting, deep-water pipelay, or offshore accommodation capacities.

Vessel outfitting for a new or enhanced offshore role can either be done in a permanent way, or on a temporary project basis. Only limited vessel modifications are needed if a modular arrangement can be made of deck-mounted equipment and facilities. A permanent new function of a trading vessel requires changes to many, if not most systems on board.

This overview paper reflects on data, trends, and insights into competitiveness and success factors of projects to expand, add, or change offshore vessel capabilities. These are illustrated by a diverse range of upgrades and conversions carried out in the marine industry. A new breed of inspection and maintenance vessels is now in demand for wind farm servicing duties. Such a vessel can be easily converted from a readily available high-end platform supply vessel.

For an offshore entrepreneur there is a range of upgrading and conversion options to choose from. He has a sea of opportunities and in fact the creativity of his vessel designers and offshore engineers has only few limits.

2. OFFSHORE VESSELS

2.1. *Floating Offshore Hull Types*

For many decades the marine offshore industry has been focusing on providing temporary or permanent floating facilities for oil and gas exploration and production activities at sea.

In recent years an international market has emerged for installation of seaborne facilities for capturing renewable energies, most notably offshore wind farms. Both in the traditional Oil & Gas (O&G) market and in the expanding wind energy activities the marine industry deploys a range of hull forms, shapes and sizes to suit specific transportation, installation, drilling, production and other service needs.

Eight types of hull forms can be distinguished for floating offshore units:

1. The most common vessel type is the ship-shaped monohull. Potentially thousands of ship type units are available worldwide. Most are self-propelled and perform more or less specialized roles. Some do not trade exclusively in the offshore industry and can also work in related sectors like heavy cargo transportation, towage and dredging. A small number of ship-shaped tanker hulls without propulsion are permanently moored at sea as oil storage facility.
2. A strong platform for transportation of large volumes and weights is the flattop cargo barge. Large rectangular barges are towed and positioned by tugboats. For a specific project execution their large decks can be configured temporarily with an array of materials and handling equipment.
3. There are only a few twin hull vessels or catamarans operating now as crane vessels on inshore or nearshore waters. But in future, larger vessels with twin bows and large deck areas will undertake very heavy lifts of complete offshore platforms.
4. Semi-submersible hulls have been designed specifically for offshore operations in unfavourable metocean conditions. They are constructed from submerged twin pontoons, connected by multiple vertical columns at either side to one topside deckbox structure housing all equipment and facilities. Semi's can be used for drilling, production, heavy lifting, pipe laying, and accommodation support roles offshore.
5. Self-elevating or jack-up units are shifted to their next work location with their legs retracted. Upon arrival the hull is jacked up along the legs which stand on the seabed when the unit is in elevated working position. Jack-ups are most suitable for drilling, temporary accommodation and windfarm installation duties (when self-propelled). The leg length of a jack-up is obviously its operating limit when working at sea.

   Both semi's and jack-ups are likely candidates for upgrading during their lifetime, as the industry moves into deeper waters and harsher climates, demanding higher payloads and heavier equipment packages (Fig. 1).
6. Unique to offshore waters is the deep draft Spar shaped hull, also named Deep Draft Caisson Vessel (DDCV).
7. Another deepwater purpose-built floating structure is the Tension Leg Platform (TLP). A few dozen of Spars and TLP's are moored permanently as hydrocarbon production facilities mainly in the Gulf of Mexico.
8. A couple of cylindrically shaped floaters have been built to date. This latest floating offshore hull type can drill in deep waters, produce hydrocarbons, store and offload crude oil and in future perhaps also LNG to shuttle tankers.

Figure 1. Upgraded drill floor lifted onto semi-submersible rig *Blackford Dolphin* (courtesy Keppel Verolme).

2.2. *Offshore Market Volatility*

Exploration drilling units engaged in the ever continuing search for oil and gas require a large fleet of supply vessels assisting them during drilling campaigns. Permanent offshore installations for production of hydrocarbons require an armada of support vessels to service them during their lifetime: For construction, transportation, and installation when starting out. For continuous supply to sustain offshore operations. And for regular offshore Inspection, Maintenance and Repair (IMR) services to keep the producing facilities in good shape.

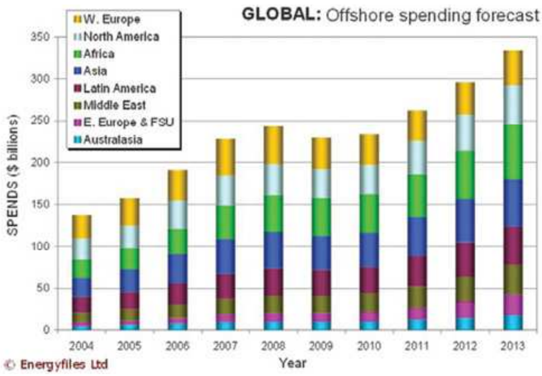

Figure 2. Global offshore E&P spending (courtesy Energyfiles).

The total spending in the offshore oil and gas Exploration and Production (E&P) industry has risen steadily until recently (Fig. 2). Expenditures include not only investments in new installations, but also on operating, maintaining and adapting existing facilities. Deepwater installation and intervention vessels were expected to come in high demand for the burgeoning Subsea Umbilicals Risers and Flowlines (SURF) sector. Many operators expanded their fleet of deepwater installation vessels in the years of rising prospects. With the oil price collapse in the second half of 2014 the tide suddenly reversed into a down cycle for the entire offshore industry. Presently an activity growth is only expected in decommissioning and removal works for those offshore O&G installations which have reached the end of their productive lives. In the offshore renewables sector a steady annual volume growth is commonly expected, both for installation and maintenance activities.

When the O&G market recovers those companies providing marine services to the offshore industry will resume taking their fair share of increased global E&P spending by providing drilling, construction/installation, logistics and IMR services. To survive in this competitive business, they will still need to continue to invest in upgrading and adapting their fleet of marine assets.

2.3. *Offshore Support Vessel Fleet Trends*

Newbuilding orders for various types of offshore support vessels (OSVs) fluctuate in short cycles. The trend over four decades shows a distinct correlation with the rise and fall of the oil price (Fig. 3). When looking closer, a typical two-year delay has been observed till recently. If the same trend continues in future, OSV newbuildings can be expected to resume only well after the world oil price has been restored to a profitable level. Perhaps longer, as the present surplus reservoir of available modern OSVs first has to gain fulltime employment.

Taking a long term view the international energy companies will continue to operate their producing assets, explore new subsea reservoirs, and invest in new field developments. The present situation of underinvestment will not be sustained. The marine transport sector therefore expects long-term restoration of occupation for their fleet. However, there is overcapacity in the near future. As example, we can look at the fleet of Platform Supply Vessels (PSVs). PSVs primarily serve offshore drilling units, construction activities and production installations worldwide. The worldwide PSV fleet has grown steadily for many years in succession, with the addition of dozens of high-capacity new units every year over a full decade (Fig. 4).

Although vessel demand and charter rates were healthy in those days, overcapacity was already looming. This has been severely aggravated by the unprecedented newbuilding surge in recent years, out of sync with the falling oil price and consequential sharp

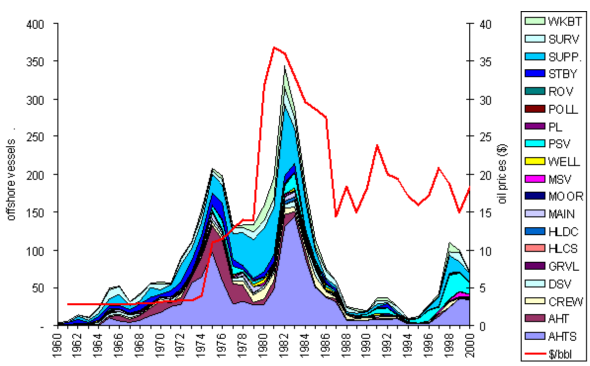

Figure 3. Offshore support fleet newbuilding orders and oil price (courtesy Douglas-Westwood). *Note:* Offshore acronyms are clarified in [1].

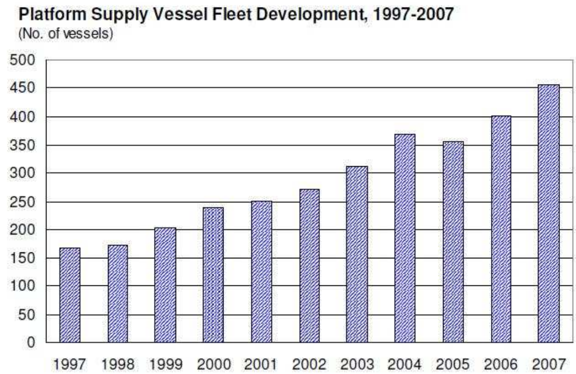

Figure 4. Worldwide PSV Fleet Development (courtesy OSC/Clarksons).

reduction in offshore field development projects. This left some of the latest newbuildings without contract upon yard delivery. Underemployed and idling offshore vessels are now trying to find more profitable employment in other marine service sectors. Repurposing vessels idled due to the industry downturn requires smart modifications to take up new roles.

3. POTENTIAL RANGE OF VESSEL CHANGES

3.1. *Adapting Existing Vessels*

For existing vessels multiple tiers of capability increase are distinguished, with increasing complexity, risks and re-building costs. Lifetime extension and modernisation of a running vessel prepares it for a new lease of life. Temporary conversion gives maximum flexibility. Capacity upgrade of a mobile offshore asset is done to keep abreast of increasing demands. Adding another function to a vessel can be attractive provided that the original function is not impaired. Changing the offshore function of a vessel requires a major conversion investment. The pinnacle of vessel modifications is reached with double conversions and complete transformations of older cargo vessels into brand new offshore assets.

3.2. *Lifetime Extension*

Lifetime extension of an ageing vessel is the easiest adaption. The renewal and refurbishment scope for gaining a new lease of productive life is clearly defined and often this is a financially attractive option. Lifetime extension projects are usually well prepared, conveniently scheduled and closely supervised by the owner’s technical staff and vessel crew.

3.3. *Modernisation*

There can be various reasons for upgrading the standards of equipment and outfitting on board offshore work vessels. Equipment breakdown frequencies, repair and maintenance costs can be the technical and economical drivers for a refit. But also the need to keep up with ever more stringent regulatory requirements, both statutory and coastal, can trigger a modernisation scope. Fitting of exhaust gas cleaning systems or retrofitting of dual-fuel engines, primarily aimed to run on LNG, is triggered by advancing emission standards. It is expected that many existing ships will receive a retrofit of a Ballast Water Treatment System (BWTS) as the Ballast Water Management Convention will enter into force in 2017. Upgrades to improve Health, Safety and Environment (HSE) operating standards can be demanded by authorities, clients, but also by the responsible vessel management.

3.4. *Temporary Conversion*

Basic conversion practice is outfitting an existing vessel or barge for a new or enhanced offshore role. That can either be done in a permanent way, or on a temporary project basis. Local hull steel structures can relatively easily be adapted to suit a new or modified purpose. Only limited vessel modifications are needed if a modular arrangement can be made of deck-mounted equipment and facilities. Sometimes a temporary Dynamic Positioning (DP) system is fitted with portable thrusters and generator sets. Flexibility to remove or adapt temporary arrangements is the general advantage.

3.5. *Capacity Upgrades*

Capacity upgrade of a mobile offshore asset is done in anticipation of market opportunities. Operators in the offshore industry may require increased drilling, production, heavy lifting, or deepwater pipelay capacities. Advanced DP capability has become the norm; anchor mooring systems are phased out. Additional equipment packages are usually placed on or above main deck level of a floating unit. The increase of topside weight necessitates creation of additional hull buoyancy volume, restoration of floating stability and regaining space. Also to compensate for extra power supply and additional crew accommodation facilities. Offshore construction vessels have a general tendency to become heavier during their operational lifetime, by incremental growth or by subsequent upgrades. Therefore, compliance to governing stability requirements requires a proactive approach from the vessel operator [2].

3.5.1. *Craneage Upgrades*

Within two decades the offshore O&G platforms installation industry has witnessed a spectacular increase in crane lifting capacity, as can be glanced from Fig. 5. This was caused by interaction of market pull and technology push.

Monohull crane vessels were operating on the North Sea in the early seventies. An upgrade of vessel workability became an essential requirement [3] and was realized with the advent of large twin crane semi-submersible heavy lift vessels. Within a decade Heerema's new semi's *Balder* and *Hermod* already got substantial upgrades of their crane capacities to keep up with new competitors. The *DB 102* (now Heerema's *Thialf*) upgraded its cranes and DP system to be on par with the *S*7000. Interestingly, the steep rise in vessel crane capacity stopped in 1985. In recent years some new crane and pipelay vessels of the monohull type with lifting capacities up to 5,000 t have been added to the world's fleet. Heerema will change the offshore game again with *Sleipnir*'s combined 20,000 t lifting capacity.

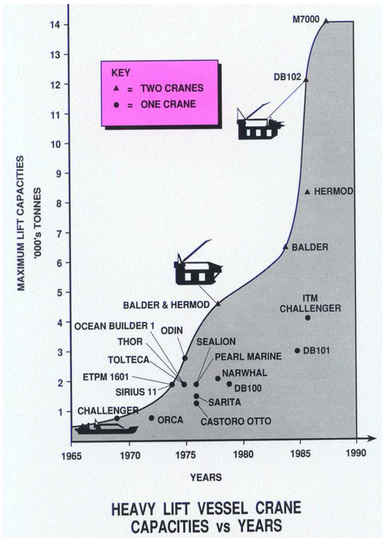

Figure 5. Offshore heavy lifting capacity increase (courtesy Heerema).

3.5.2. *Drilling Upgrades*

From the mid nineties the demand for deep water capable drilling rigs outpaced the availability of these units. To meet this demand, which has continued for more than a decade, fast track and economical solutions were required. Repeatedly the solution was found in converting older generation conventionally moored drill ships. These had limited drilling depth and positioning ability. The oldies were then substantially upgraded to operate in ultra deep water depths and utilize the most sophisticated available technology. Station keeping was upgraded to incorporate full DP capability, and state-of-the-art drilling equipment was installed.

The earlier generation drillships had relatively slender hulls and limited positioning power. To operate higher drilling loads in deeper waters their hulls, drilling and positioning systems needed considerable expansion. Adding sponsoons or so-called blister tanks on the ship sides became quite common. One example of a substantial drillship capacity upgrade is presented in Table 1. Engineering and execution of this major upgrade was done in Finland and resulted in an elaborate DP system controlling no less than 17 thrusters. This is possibly the largest number ever fitted.

Table 1. Drillship major capacity upgrade (source Deltamarin).

Drillship Particulars	***Sedco 445***	***Deepwater Navigator***
Max. Water Depth	400 m	2,500 m
Max. Drilling Depth	6,100 m	7,600 m
Hull Dimensions	136 × 21 × 10 m	168 × 26 × 3 m
Thrusters	13 Thrusters	17 Thrusters
DP System	DP 2	DP 3

Re-activating and upgrading early generation drillships was still feasible during the exceptional heydays of the overheated newbuilding market. For example, the drillship *Neptune Explorer* was re-activated and upgraded in Singapore some years ago. Although investment and completion time were substantial, at the time they were still about half the equivalent newbuilding price and delivery time. An upgrading campaign for three old Brazil-based drillships was also substantial. The extensive scope of work included new drilling packages, replacement of entire stern sections, fitting of accommodation blocks, sponsoons, and heliports.

3.6. *Additional Functions*

Adding another function to a vessel for better serving offshore installation and transportation markets is a balancing act with maintaining the original vessel capacities. This to offset upgrading costs with extra revenue potential. Through a clear strategy for limited upgrade and conversion the vessel's physical growth and associated OPerating EXpenditure (OPEX) can be limited.

Examples of additional functionalities for existing offshore vessels are: Heavy lifting, pipe laying, mooring line installation, cable/umbilical laying, trenching, diving or Remotely Operated Vehicle (ROV) support. In most of these cases the twin-role vessels have managed to retain their original function to a large extent.

3.7. *Changing into New Function*

Changing the offshore function of a vessel requires a major conversion investment. The original power plant, propulsion equipment, tank spaces below deck, and accommodation deckhouse may be retained. But for the new offshore role a multitude of equipment and supporting systems will be fitted, with associated weight, space and power demands.

With a particular offshore function and capacity in mind a marine asset operator may develop and evaluate various options for newbuilding or conversion of existing vessels. For an offshore entrepreneur there is a range of available merchant vessel types and

Table 2. Examples of merchant vessel function changes executed

Original Vessel	New Offshore Function
Fishing Trawler	Emergency Response Rescue Vessel, Seismic Survey Vessel
Paper Carrier	Seismic Research Vessel
Semi-Submersible Heavy Transport Vessel, Barge Carrier	Rock Dump Vessel, Rigid or Flexible Pipe Lay Vessel, Trenching Support Vessel, Construction Support Vessel, Cable Lay Vessel, Crane Vessel
Heavy Module Carrier	Flexible Pipe Lay Vessel, Crane Vessel
Tanker	FPSO, FSO, MCV, Shuttle Tanker, WSV, Heavy Transport Vessel
Bulk Carrier	Rigid Pipe Lay Vessel, Crane Vessel, Power Vessel
Ro-Ro Cargo Ship	Cable Lay Vessel
General Cargo Ship	Cable Recovery Vessel
Passenger / Car Ferry	Accommodation and Repair Vessel, Wind Farm Support Vessel
Train Ferry	Floating Production Unit
Inland Container Vessel	Arctic Living Quarter Barge
Liquefied Natural Gas Carrier	Floating Storage Re-gasification Unit, Floating LNG liquefaction unit

potential modifications to choose from (Table 2). He has a sea of opportunities and in fact the creativity of his ship designers and offshore engineers has few limits.

Obviously it is not only the vessel type that can be modified. A permanent new function of a trading vessel eventually requires adaptations for many, if not most systems on board.

Offshore units can also change functions, as can be glanced from Table 3. In many cases the hull capacity has been boosted to play host to heavier equipment packages.

Table 3. Examples of offshore unit function changes executed

Original Unit	New Offshore Function
Cable Lay Vessel	Diving Support Vessel, Trenching Support Vessel, Flexible Pipe Lay Vessel, Accommodation and Support Vessel, Seismic Vessel, Marine Diamond Mining Vessel
Drillship	Cable Lay Vessel, Flexible Pipe Lay Vessel
Drilling Jack-up	Accommodation Jack-up, Production Jack-up
Accommodation Semi	Drilling Semi, Production Semi, Tender Support Vessel
Crane Semi	Production Semi
Drilling Semi	Production Semi, Accommodation Semi, Spacecraft Launch Platform, Mobile Radar Station

Semi-submersible hulls can be modified for yet another offshore function. Most of times additional topside weight and/or Variable Deck Load (VDL) have to be accommodated. Mooring equipment or DP power upgrade bring more weight and require hull space. For this extra pairs of columns and/or blister tanks are added to gain buoyancy and stability.

4. POPULAR OFFSHORE CONVERSIONS

4.1. *FPSO Conversions*

Conversion of crude oil tankers into Floating Production Storage and Offloading (FPSO) units or Floating Storage and Offloading (FSO) facilities are very common. Most FPSOs operating to date are ship-shaped tanker conversions rather than barge-shaped newbuildings. Numerous FPSO conversions have been carried out successfully at Singaporean yards. Experience in design, construction, and installation is exchanged at industry fora [4].

Advantages of FPSO conversions over newbuildings are the significant cost and time savings. One starts with a thorough inspection of a suitable tanker hull. When found in good condition the repair, refurbishment and overhaul activities can then be well planned into the conversion schedule. Steel repairs and coating works as lifetime extension of the hull also include extension of the fatigue life of structural connections. Major additions for the FPSO role are the turret and mooring system built into the hull structure and the fitting of process equipment in modules above deck.

Provided that the various interfaces are well managed an FPSO conversion can be completed within approximately half the time of an equivalent newbuilding project. If the tanker propulsion plant is retained and re-activated it can serve during an FPSO delivery voyage to its offshore location, and for power generation from then onwards.

Usually, the crude oil tanks constituting the main portion of hull volume are utilized for oil production storage offshore, awaiting periodical offloading by shuttle tankers. In case

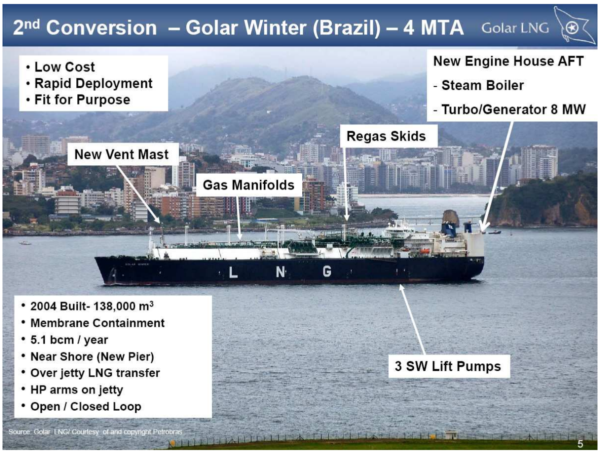

Figure 6. Conversion of LNG carrier into FSRU (courtesy Petrobras).

the original deck area and cargo capacity is insufficient for the desired FPSO production capacity, sponsoons can be added at the hull sides during conversion [5].

4.2. *FSRU Conversions*

FPSO tanker conversion experience can also be applied in the related field of gas storage and re-gasification. As an alternative to traditional shore-based liquid gas receiving terminals nowadays projects for nearshore floating storage are developed. A Floating Storage and Re-gasification Unit (FSRU) receives liquefied gas from shuttle carriers, evaporates and pressurises the gas into a consumer pipeline grid. The scope for converting an existing Liquefied Natural Gas (LNG) carrier is overseeable and easily repeatable (Fig. 6). Based on readily available LNG carriers, which have usually been maintained in excellent condition, the time to market can be a fraction of building an entire new gas terminal facility onshore.

An ongoing more elaborate sandwich-style floater conversion in Singapore will turn an existing LNG carrier into a new Floating Liquefied Natural Gas (FLNG) producing unit.

4.3. *Conversion of Platform Supply Vessels*

A modern PSV has a large unobstructed cargo deck, ample deck cargo carrying capacity, high bollard pull, and excellent station keeping at sea. This makes this vessel type very suitable for a variety of support roles. And with relative little effort the range of offshore applications can be expanded.

High-end PSVs are likely candidates for modular conversion into underwater construction and intervention roles. Deck mounted modules housing overboarding equipment, power supply, control and accommodation facilities can be fitted rapidly in a semi-permanent layout. This flexibility allows for later expansion or changeout.

PSVs can be converted into a variety of subsea inspection, intervention and construction support roles: geophysical survey, bathymetric and position survey, diving, well stimulation, cable lay, flexible pipe lay, umbilical lay, and trenching support are amongst the duties that can be assumed by these offshore workhorses. An illustrated example of fitting modular cable lay equipment on a supply vessel deck is found at the Drammen Yard website.

Many shipowners have invested in newbuilding programs for high-capacity PSVs in the booming years. This has caused an unprecedented growth of the world's supply vessel fleet. Demand and charter rates then have fallen dramatically. Not all vessels in the large PSV fleet, young and ageing, will find employment in the offshore transportation industry. To restore market balance several units have gone into cold lay-up or have been withdrawn completely. Newbuilds may still be lucky to get long term charters to cover their high CAPital EXpenditure (CAPEX) costs. In the spot charter market it will be difficult to harvest sufficient annual earnings. Conversion of vacant vessels to enter diversifying offshore construction sectors may be an interesting option for buyers of surplus tonnage. Some are venturing into the offshore windfarm industry.

4.4. *Conversion into Windfarm Support and Installation Vessels*

The market for offshore wind farm projects is growing fast and is rapidly developing in practically every part of the world, with high growth rates ranging from 10 to 40% per year expected over the next 10 years. This calls for productive wind turbine installation vessels, but also a for a fleet of service operations vessels supporting the daily inspection and maintenance operations by resident technicians at sea during the entire windfarm's lifetime. As turbine numbers and distances to shore increase, a new breed of Wind Farm Support Vessel (WFSV) is emerging. It is an accommodation vessel capable of close manoeuvring, and stable crew transfer to and from the wind turbines ('walk-to-work').

A creative combination with the availability of idling high-end offshore supply vessels, overcapacity at design houses and shipyards now leads to feasible projects for support vessel conversions [6]. One such vessel conversion is completed this summer in Norway. Taking advantage of the large deck space, thruster power and manoeuvrability of a typical modern PSV, the conversion mainly comprises fitting of an accommodation module and a motion compensated offshore gangway for personnel transfer. If the scope is treated by Classification Society and Flag State as a minor conversion, then no updating of existing vessel systems to comply with newbuilding rules and regulations is required. A case study [6] concludes that with a limited conversion scope and short charter time there is an advantage for the PSV conversion over the comparable WFSV newbuilding alternative. For a long-term wind farm services contract a purpose-built new vessel is preferred.

Drilling units are in large surplus as well these days, even brand new high-spec units are laid up without employment. For each offshore windfarm development a large number of tall wind turbines need to be installed efficiently. This has inspired the developers of a new type of monohull Wind Turbine Installation Vessel (WTIV). It is based on conversion of the most powerful latest generation of DP deepwater drilling vessels built in series in Korea during recent years. Several advantages of this novel windfarm installation concept over existing jack-up wind turbine installers are claimed.

4.5. *Upgrading and Conversion of Semi-Submersible Heavy Transport Vessels*

The worldwide fleet of semi-submersible heavy transport vessels counts well over 70 units now and is broadly divided into three vessel types: open stern type, stern + bow type, and

Figure 7. Hull widening of heavy transport vessel *Blue Marlin* (courtesy Dockwise).

dockship type. Their heavy and sometimes awkward sized cargoes are usually buoyant but not seagoing. Relocating offshore drilling and production units, or large modules thereof, is the prime transportation business of these heavy project cargo carriers. They load and discharge their valuable cargoes by the float on/float-off method in sheltered waters of sufficient depth.

Two of the largest vessels in the fleet of market leader Dockwise have gained substantial carrying capacity by jumboising their hulls. Increasing vessel capacity by inserting a new midbody section is a fairly common upgrading method for merchant cargo, passenger and dredging vessels. It usually requires no increase in propulsion power. Widening a hull by fitting additional side sections gains stability at the cost of hull resistance (see Fig. 7). Widening a vessel to increase cargo capacity by cutting the ship lengthwise, putting in a new long section in along the entire centreline has been done in drydock for other ship types, but is a much more complex conversion scope.

Heavy transport vessels have large flush decks of high strength. Most of the below-deck spaces are ballast tanks. These spaces can be turned into additional engine rooms and thruster rooms when a heavy cargo carrier is converted into an offshore installation vessel. Some carriers have already been converted into rock dumping vessels, trenching support vessels, pipe layers or cable layers (Table 2). With the recent newbuilding surge for geared dockships and fluctuating demand for industrial heavy cargo transport it was already expected that more dockships would be converted for offshore duties. This has indeed happened recently in Germany.

5. COMPLEX CONVERSIONS

5.1. *Conversion Success Factors*

Major vessel conversions can be done successfully and can be competitive with newbuilding options. And in some cases an overriding time-to-market requirement leaves no other option than realizing a fast-track project based on converting a suitable vessel at hand.

Not all vessel conversion projects are reported to have been completed on time and within budget. Important factors contributing to conversion success are dedicated and flexible project management, and proper engagement of specialized and experienced partner firms. The shipyard should be selected on basis of its proven track record in planning and delivering complex conversion projects. Good facilities and infrastructure are a prerequisite. Staff of yard, subcontractors and suppliers must be qualified and experienced. Project partners must be willing to accept contractual responsibilities and focus on mitigating mutual risks. And seamless co-operation between parties including the Classification Society is required. Lessons learned from large scale conversion projects, on preparation, engineering, management and execution, are shared at offshore industry fora [7].

Some ship repair yards and design houses specialise in the fine art of vessel upgrading, refit and conversion. Every conversion proposal has to be considered first in the context of ship structure, stability and safety. In the new configuration and service the unit must meet Class and statutory standards. Bureau Veritas is the first Classification Society to publish offshore ship conversion guidance [8]. They set out the requirements for structural assessment when operators are considering converting a ship into an offshore unit or making major modifications to offshore units in service.

5.2. *Double Conversions*

Sometimes a converted cargo or passenger vessel is reinstated into its original function. Even de-jumboising can occur. These seemingly illogical re-conversions can follow from a swing in the shipping market.

Double conversions of the same vessel are rare. Only few vessels get converted twice during their lifetime, to adapt them again for changed offshore workscopes. Two rather unique examples are presented here:

1. The conventional roll-on/roll-of cargo vessel *Sentosa* (ex *Mercandian Continent*) was destined for conversion into the sophisticated cable lay vessel *Kraka* at a Croatian shipyard. But the yard went bankrupt and the unfinished and disputed project laid idle for 7 years. Eventually the Danish entrepreneur Lauritzen acquired it and towed it to a German yard for another conversion, turning it into a new type of DP Accommodation and Support Vessel (ASV). Re-baptized *Dan Swift* it is since engaged in deep water oil development projects offshore Brazil.
2. The semi-submersible heavy transport vessel *Dock Express 20* once was the largest dockship in the Dockwise fleet. It was first converted into a cable layer and operated under the same name for a good number of years. Upon expiry of its long term charter it was acquired by De Beers Consolidated Mines and retrofitted with a complete subsea excavation and surface processing installation for diamond mining offshore. The rejuvenated ship is operated by De Beers as the Marine Diamond Mining vessel (MDMV) *Peace in Africa* off the Namibian coast (Fig. 8).

5.3. *Complete Transformations*

The summit of vessel conversion is the complete transformation of an older cargo vessel hull into a brand new offshore asset. Availability of a suitable hull in good condition is

Figure 8. MDMV *Peace in Africa* (courtesy De Beers).

an instant gain at the start of such an extreme makeover. This benefit may fade away somewhat over time, as the given hull structure may prove less than optimal for efficient arrangement of new equipment and facilities. Heavy structural loads may find insufficient bearing and may require costly new steel constructions for adequate support. Integrating massive local support structures into the given scantlings of an existing cargo vessel hull requires ingenuity and flexibility of the designer.

In 1985 the newly formed offshore engineering contractor Allseas Engineering decided to convert its first asset from the bulk carrier *Nathalie Bolten* into the pipeline installation vessel *Lorelay*. The vessel was initially also turned into a dockship to receive barges loaded with stacks of pipe joints in her dockhold by the float-in method.

In those days the *Lorelay* was a novel concept in the offshore installation industry. It was the first dynamically positioned pipe lay vessel and set the standard for all DP pipe lay vessels built around the world in the next 25 years.

In the nineties Allseas repeated the successful transformation of an older cargo vessel hull into a state-of-the-art pipe lay vessel, albeit at larger scale. During the metamorphosis of the bulk carrier *Trentwood* into the large DP pipe lay vessel *Solitaire* (Fig. 9) a description of the full conversion and fitting of pipe lay systems was published [9].

Later the Allseas fleet was joined by another pipe lay vessel converted from an existing bulk carrier. This time the brand new bulk carrier *Geeview* was converted into the mid-size pipelayer *Audacia*. In this case the propulsion plant and aftship were retained. Increase in pipe lay and pipe handling capacities was effected already during the conversion itself and some margin was kept for further upgrade.

One of the most unusual vessel transformations was the extraordinary conversion of the German ice-class train ferry *Karl Carstens* into a DP offshore Floating Production Unit (FPU). The hull was substantially widened and loaded topside with process equipment modules and handling cranes. Also, a disconnectable turret system, a DP2 system and new accommodations plus helideck were fitted. As *Helix Producer I* she then started hydrocarbons production in the Gulf of Mexico. This purposeful offshore vessel transformation is a typical example where time-to-market was an all-overriding argument in the extremely volatile shipbuilding market in the 2004-2008 period.

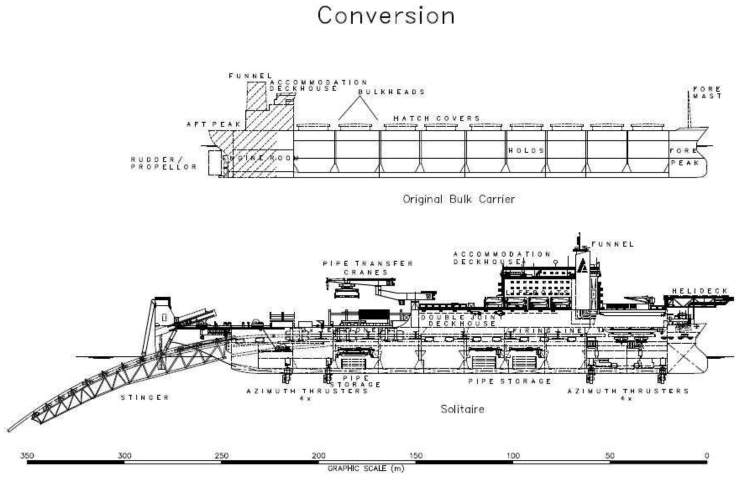

Figure 9. Full conversion of bulk carrier into large DP pipelay vessel (courtesy Allseas).

5.4. *Encore: Upgrading Again*

Soon after the first successful years of *Solitaire* offshore operations Allseas realized that the emerging ultra-deepwater construction market demanded substantial larger capacities of onboard pipeline installation equipment. History repeated itself and in 2005 *Solitaire* got a series of upgrades: Aftship strengthening and buoyancy addition, tensioners replacement, Abandonment and Recovery (A&R) winch and sheaves upgrade, stinger elongation, and corresponding stinger handling system upgrade (Table 4).

Table 4. Particulars of *Solitaire* pipe lay capacity upgrade.

Pipelay Equipment	Original Conversion	Upgrade
Reference	[9] van Wijngaarden, 1994	[10] Steenhuis *et al.*, 2007
Tensioners	4 × 100 t	3 × 350 t
A&R Winch	400 t	1050 t
Stinger	110 m	140 m

The various modifications of *Solitaire* to increase installation capacity for deep water pipelines and Steel Catenary Risers (SCR) have been realised [10] as can be viewed on the Allseas corporate website. At a later stage two additional thrusters were fitted in the aft sponsoons and Life Saving Appliances (LSA) capacity was upgraded, followed this year by fitting a bigger offshore crane aft.

Along with lifetime extension works further plans were executed for upgrading the successful *Lorelay* to add tensioner and thruster power to this vindicated pipelayer. And younger sister *Audacia* already received accommodation, crane and thruster upgrades.

6. CONCLUSIONS

Capturing market opportunities in the offshore oil & gas and wind industries enables vessel operators to adapt their assets in various ways. There are multiple tiers of vessel capability increase. Each tier brings increasing complexity, risks, and re-building costs.

Lifetime extension and modernisation stretch the productive life of units. Capacity upgrade of a mobile offshore asset keeps it abreast of increasing demands. Adding another function to a vessel can be attractive provided that the original function is not impaired. Changing the offshore function of a vessel requires creative design solutions and a major conversion investment. The ultimate step of vessel re-building is the complete transformation of an older cargo vessel hull into a brand new offshore unit.

Entrepreneurial operators match an emerging demand for specialised offshore vessels with availability of suitable vessels for conversion. Opportunities are realised to create a new breed of windfarm inspection and maintenance vessels by converting surplus platform supply vessels.

Vessel outfitting for a new or enhanced offshore role can either be done in a permanent way, or on a temporary project basis. Only limited vessel modifications are needed if a modular arrangement can be made of deck-mounted equipment and facilities. A permanent new function of a trading vessel requires changes to many, if not most systems on board.

Even major vessel conversions can be done successfully and can be competitive with newbuilding options. In some cases an overriding time-to-market requirement leaves no other option than realising a fast-track project based on converting a suitable vessel at hand. Compared to newbuilding a full conversion can at times be done at typically half the construction cost and project delivery time. Capabilities of the conversion yard and integrated project management are crucial for satisfactory delivery of a specialty product.

Upgrades and conversions of offshore vessels expand their operational and economical portfolio and serve the offshore industry in reaching spectacular advances in transport, construction and installation performance.

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WEBSITES

Samples of excellent video movies on vessel upgrades and conversions can be viewed on the internet. The Drammen website http://www.drammenyard.no features an animation of quickly fitting a modular cable lay equipment spread on a large supply vessel deck. The Allseas website http://www.allseas.com/uk/20/equipment/solitaire.html shows an edited video movie on significant capacity upgrades of the pipe lay vessel *Solitaire*.

Some of the upgraded and converted ships mentioned in this paper also feature on http://www.uglyships.com. No doubt for displaying their good looks as true offshore work vessels.

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Martijn van Wijngaarden is currently Certification Manager for Heerema's newbuilding SSCV *Sleipnir*, world's largest twin crane vessel under construction in Singapore. Previously he held the same position for the DCV *Aegir* newbuilding in Korea. Concurrently he was senior lecturer at Delft University of Technology. Within the Master curriculum for Offshore and Dredging Engineering his main subject was Floating Offshore Structures. Elected as offshore industry representative he has become an active member of Lloyd's Register's Offshore Technical Committee.

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