An introduction to offshore platforms

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An introduction to offshore platforms

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Offshore platforms

- An offshore platform is a large structure used to house workers and machinery needed to drill and/or produce natural resources (i.e. oil, natural gas, mineral ores etc.) through tunnels/wells in the ocean bed. Depending on the circumstances, the platform may be attached to the ocean floor, consist of an artificial island, or be floating.
- **Location**
  - Generally on the continental shelf.
  - Recent trend is towards drilling and production in deeper waters.

Offshore platforms

- **Scope:** Around 6,500 offshore oil and gas installations distributed in some 53 countries.
- **Regions:** US Gulf of Mexico: 4,000; Asia: 950; Middle East: 700; Europe, North Sea and North East Atlantic: 490; West Africa coast: 380; and South America: 340.
- **Objectives:** They are used for various applications:
  - Drilling.
  - Preparing water or gas for injection into the reservoir.
  - Processing oil and gas.
  - Cleaning the produced water for disposal into the sea.
  - Accommodation facilities.

Offshore platforms

- **Compositional structure**
  - Wellheads are located on the platform and directional drilling allows reservoirs to be accessed at both different depths and at remote positions up to 8 kms from the platform.
  - Many platforms also have remote wellheads attached by umbilical connections, these may be single wells or a manifold centre for multiple wells.
  - **Feature:** Larger lake- and sea-based offshore platforms are some of the largest moveable man-made structures in the world.

Offshore platforms ………………………. General Technical Details

- Offshore platforms are self-sufficient in energy and water needs, housing electrical generation, water desalinators and all of the equipment necessary to process oil and gas such that it can be either delivered directly onshore by pipeline or to a Floating Storage Unit and/or tanker loading facility.

- **Main elements in the oil/gas production process:** Wellhead, production manifold, production separator, glycol process to dry gas, gas compressors, water injection pumps, oil/gas export metering and main oil line pumps.

- **Special features:** Larger platforms are assisted by smaller ESVs (emergency support vessels) e.g. when a search and rescue operation is required.

- During normal operations, PSVs (platform supply vessels) keep the platforms provisioned and supplied, and AHTS vessels can also supply them, as well as tow them to location and serve as standby rescue and firefighting vessels.

- Human crew features: Because of the cost intensive nature of operating an offshore platform, it is important to maximise productivity by ensuring work continues 24 hours a day. This means that there are essentially two complete crews onboard at a time, one for day shift and the other for night shift. Crews will also change out at regular intervals, nominally two weeks.

- There are several distinct types of platforms:
  - Fixed Platforms
  - Compliant towers
  - Semi-submersible Platforms
  - Jack-up Platforms
  - Drillships
  - Floating production systems
  - Tension-leg platforms
  - SPAR Platforms
  - Normally unmanned installations

- **Fixed Platforms -** Either built on concrete and/or steel legs anchored directly onto the seabed, supporting a deck with space for drilling rigs, production facilities and crew quarters.
- **Features:** Very long term use.
- **Material and structure:** Various types of structure are used, steel jacket, concrete caisson, floating steel and even floating concrete.
- **Economic feasibility:** Feasible for installation in water depths up to about 520m.
- **Major types:** Steel jacket and concrete platform.

- **Components:**

a. Superstructure: 'topsides' supported on a deck, which is fixed (mounted) on the jacket structure. Consists modules which house drilling equipment, production equipment including gas turbine, generating sets, pumps, compressors, a gas flare stack, revolving cranes, survival craft, helicopter pad and living quarters with hotel and catering facilities. **Weight** - up to 40,000 tonnes.

b. Substructure: Either a steel tubular jacket or a pre-stressed concrete structure.

- **Popular choice:** Steel jacket in the past, but recently trend towards concrete platforms.

- **Design parameters:** Each offshore platform is uniquely designed for the particular reservoir condition, location, water depth, soil characteristics, wind, wave and marine current conditions.

- **Construction depths:** Normal in water depth from a few meters (5m-25m) to around 400m, Special technology up to 520m.

- **Environment conditions:** Can be severe. For example in North Sea - a hundred-year return period wave with a height of up to 31m and a wave period of between 15 and 20 seconds; storm duration: 6 hours; wind speed - 220 km/h.

Offshore platforms …………. Fixed platforms – steel jacket platform

- **Basic description:** Based on a pile foundation. “Substructure" or "jacket" is fabricated from steel welded pipes and is pinned to the sea floor with steel piles, which are driven through piles guides on the outer members of the jacket.
- **Components:** Piles are thick steel pipes of 1m to 2m diameter and can penetrate as much as 100m into the sea bed. Weight - up to 20,000 tonnes.
- **Maintenance:** Maintenance must be carried out including the cathodic protection (i.e. to prevent corrosion).

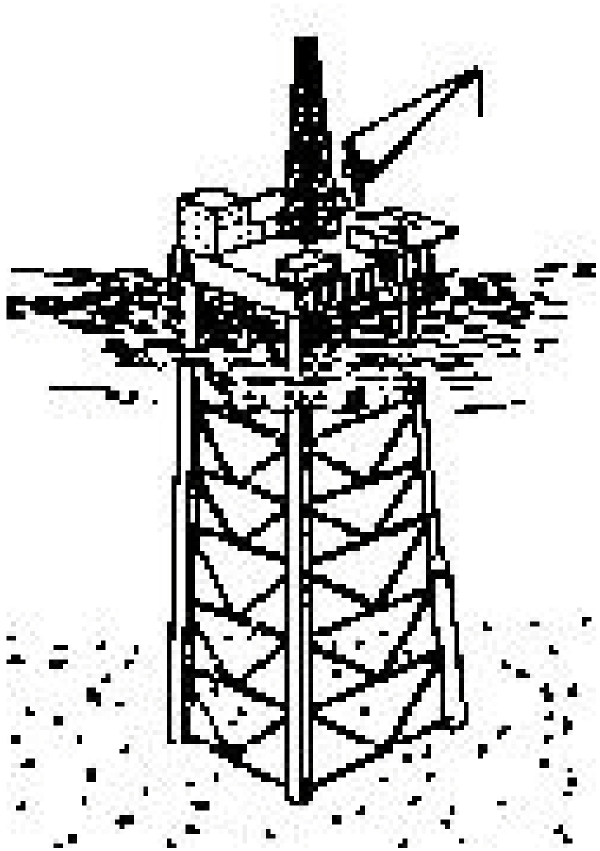

Fig. 1. A steel jacket structure.

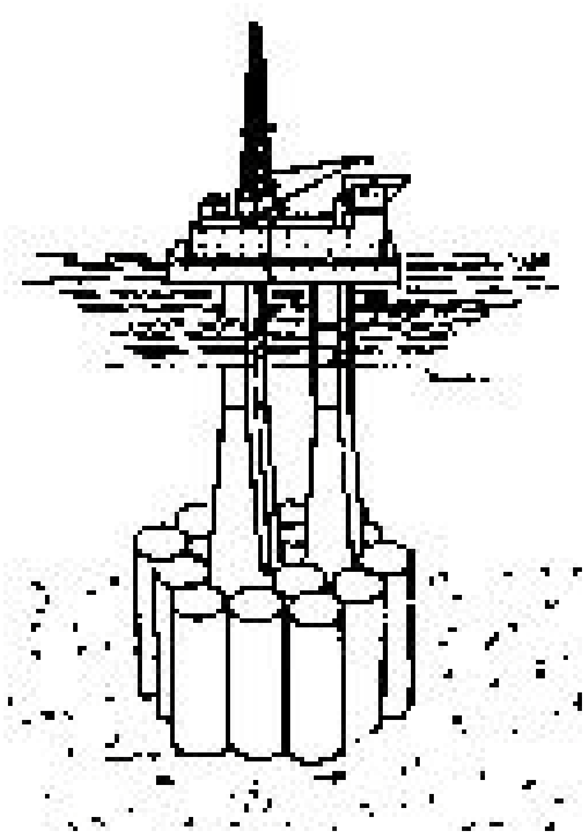

Fig. 2. A concrete gravity platform.

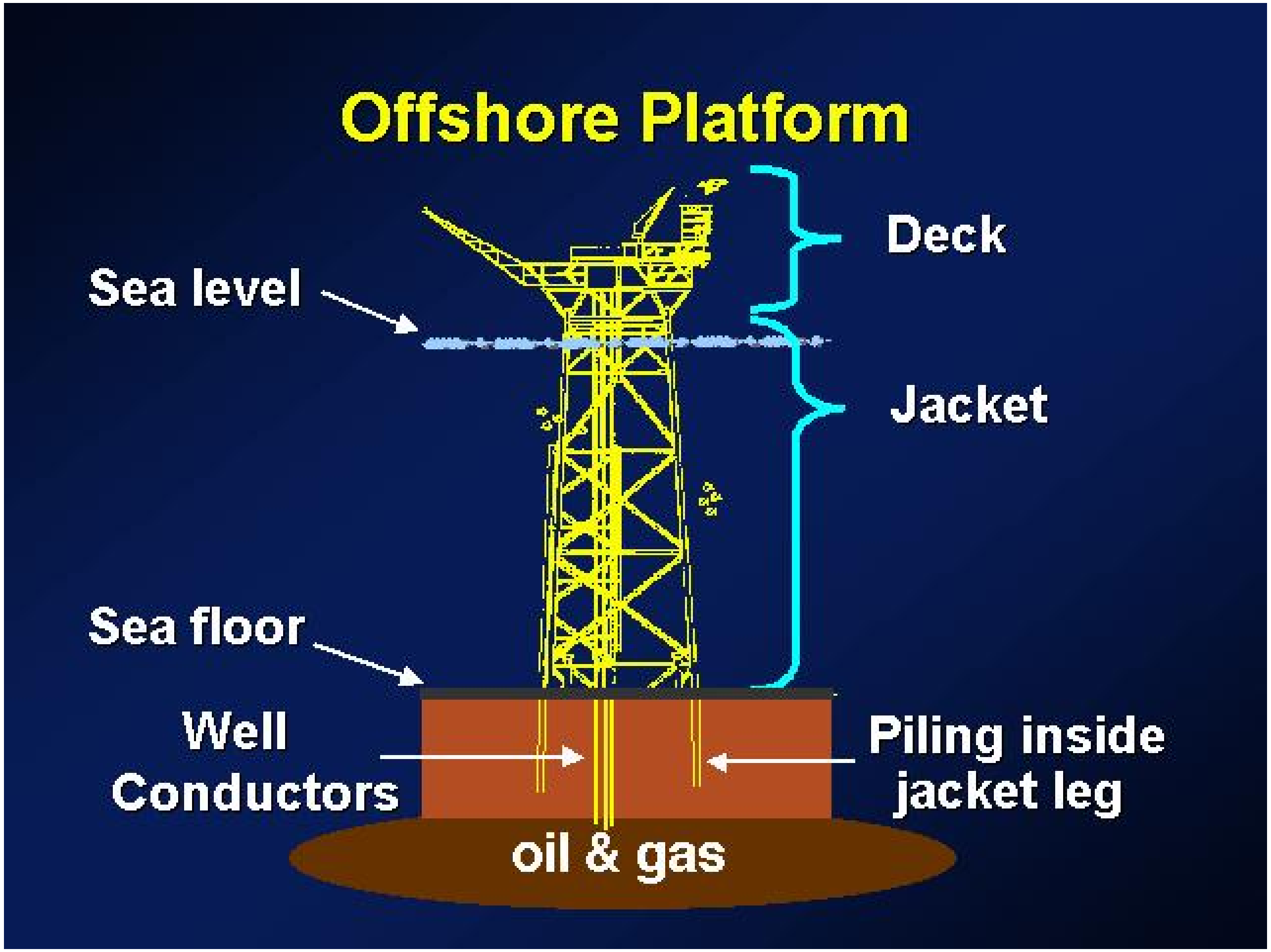

Fig. 3. A typical steel jacket platform.

- **Design parameters:** Required strength, fatigue, load and life cycle. The pile design must result in a balanced combination of diameter, penetration, pile wall thickness, and spacing.

- Critical component: Pile - cost of pile foundation and installation is around 40 % of the total cost of the platform structure.

DESIGN EXAMPLE: For example, the typical design for a steel jacket of 150m is as,

- At the seabed the dimensions of the structure are 70m x 65m and at the top 56m x 30m (i.e. assuming the top is about 15m above sea level).

- The structure weights about 18,500 tonnes and would support topsides of up to 21,000 tonnes.

- The jacket can resist forces of up to 50 MN in compression and 10 MN in tension as well as having large resistance to lateral loads.

Note that in general for offshore platforms the compressive loads are 4-6 times of tensile loads.

- **Maximum design forces for steel jacket platform are:** Vertical load – 40-60 MN; Horizontal load – 4 – 7 MN; and Overturning moment – 8 – 12 GN.m.

- **CONCLUDING REMARKS:** The fixed structures can withstand immense vertical loading and overturning moments as they are designed to be resistant to toppling from very large wave fronts.

- They can also withstand vertical loadings and the overturning moment imposed by many renewable energy devices.

- Not advisable to impose any further lateral loading on the offshore installation as this will affect the overall strength of the platform creating a potential safety hazard. Detailed structural analysis needs to be carried out to determine the suitability of re-using each fixed installation as OREC (offshore renewable energy center).

Fig. 4. A typical concrete platform.

Offshore platforms ……………. Fixed platforms – Concrete platform

- **Basic description:** Concrete platforms are generally larger structure than steel jackets and are not piled but instead sit on the seabed, stabilized by their own massive weight (i.e. gravity supporting).
- **Range of applicability:** Fixed concrete offshore platforms can serve almost any offshore purpose such as drilling and exploration, oil and gas production and storage. Weight - over 7, 50,000 – 10, 00, 000 tonnes.
- **Main reasons for their selection:**
  - ✓The possibility of incorporating oil storage, especially for large field areas.
  - ✓Cheaper installation cost.

Offshore platforms ……………. Fixed platforms – Concrete platform

- ✓ Majority of the equipment installation and hook-up is performed onshore, limiting the amount of more expensive offshore installation work.

- ✓ Larger than steel jackets, so permit greater production and in the same time reduce the total number of platforms required for the development of a field.

- ✓ Concrete does not require heavy maintenance and does not suffer any significant reduction in load-carrying capacity over the years.

*** So they are viewed as a better choice than steel jacket platforms.***

- **Major drawbacks:**

  - Relatively expensive initial installation cost, compared to steel jacket.
  - Till today no feasible means of removing (decommissioning) the structure has been defined.
  - Since, they cannot be removed, they are considered damaging to the environment and ecology.

- **Construction practice:**

  - The base and the deck are built separately and then they are joined while the base is partially submerged.
  - The platform is towed over to the desired location.

- The platform is built of reinforced concrete using the Condeep (i.e. concrete deep water structure) technology.

- **Design parameters:** Foundation is designed to withstand forces from the weight of the structure with deck loads, stored oil and ballast. Also environmental parameters as waves, currents and winds and in some locations, earthquakes and ice loading are considered.

- **DESIGN EXAMPLE:** For example, the typical design of a concrete platform (i.e. in the North Sea) is as,
    - The base consists of 19 interconnected 61m high cylinders.

- Three of the base cylinders extend upwards as towers to support the deck some 170meter above the sea floor. The caisson measures 100m across and a base area of 6300 m2.

- The wave action causes vertical and horizontal forces on the structure, as well as an overturning moment. The design also takes into account several possible loads combinations including those on the submerged part of the structure, the ballast and live loads.

- Maximum design forces are as: Vertical load – 1750 – 2250 MN; Horizontal load - +/- 475 – 525 MN; and Overturning moment – 18 – 22 GN.m.

- **CONCLUDING REMARKS:** Concrete structures have immense strength and are normally can be more than 400 times stronger than fixed steel structures.

- Furthermore, they can be expected to withstand the vertical, lateral and overturning moments imposed by many renewable energy devices.

- Since, theoretically they are more feasible to be re-used as OREC (offshore renewable energy center), in future world interest is likely to grow in them.

Offshore platforms ……………. Fixed platforms – Concrete platform

- **RECENT EXAMPLE:** Troll A platform (Norway) has an overall height of 472 meters and weighs 656,000 tons. It has the distinction of being the tallest structure ever moved by mankind. The platform stands on the sea floor 303 meters below the surface of the sea. The walls of Troll A's legs are over 1 meter thick. TOWING TIME = 7 days.

Fig. 5. A deep and large concrete fixed platform (Troll A platform, NS, Norway)

- **Basic description:** They consist of narrow, flexible towers and a piled foundation supporting a conventional deck for drilling and production operations.

- **Additional features:** With the use of flex elements such as flex legs or axial tubes, resonance is reduced and wave forces are de-amplified. This type of rig structure can be configured to adapt to existing fabrication and installation equipment.

- Compared with floating systems, such as Tension-leg platforms and SPARs, the production risers are conventional and are subjected to less structural demands and flexing.

- This flexibility allows it to operate in much deeper water, as it can 'absorb' much of the pressure exerted on it by the wind and sea.
- **MAIN ATTRACTION:** Despite its flexibility, the compliant tower system is strong enough to withstand even hurricane conditions.
- **Design criteria:** To sustain significant lateral deflections and forces.
- **Applicable water depths:** Used in water depths ranging from 450m to 900 m.

RECENT EXAMPLES: "Petronius" Compliant Tower, 1,754 ft water depth – Gulf of Mexico, USA.

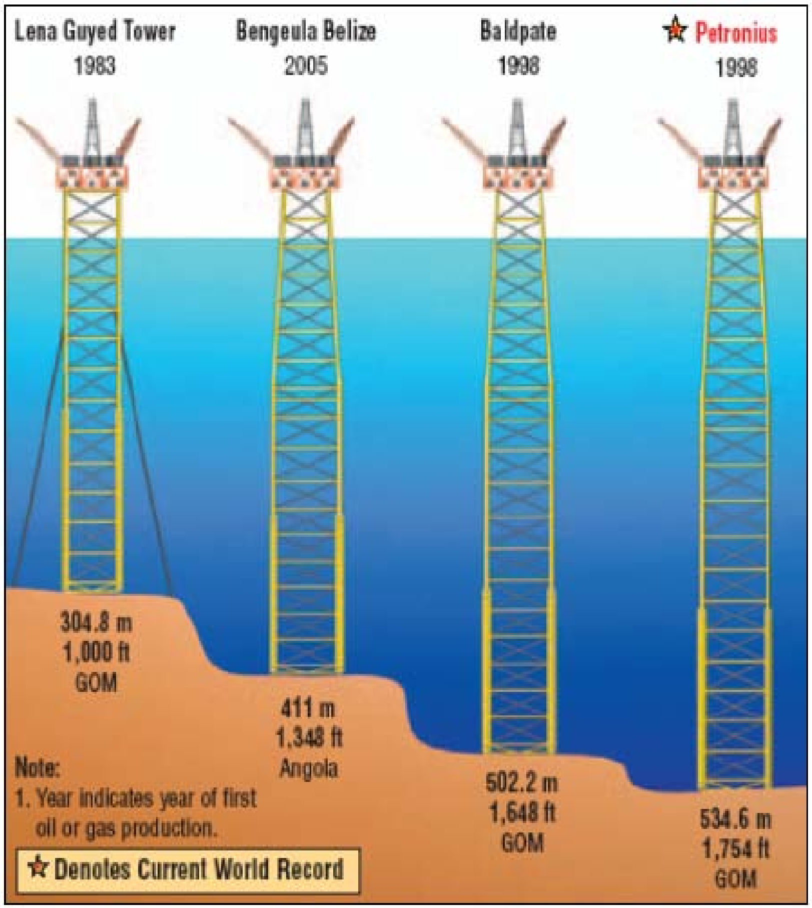

Fig. 6. A deep compliant tower Petronius, Gulf of Mexico, USA.

- **Brief description:** They have legs of sufficient buoyancy to cause the structure to float, but of weight sufficient to keep the structure upright.

- **Basic advantage:** Semi-submersible rigs can be moved from place to place; and can be ballasted up or down by altering the amount of flooding in buoyancy tanks; they are generally anchored by cable anchors during drilling operations, though they can also be kept in place by the use of dynamic positioning.

- **Applicable depths:** Used in depths from 180m to 1,800m.

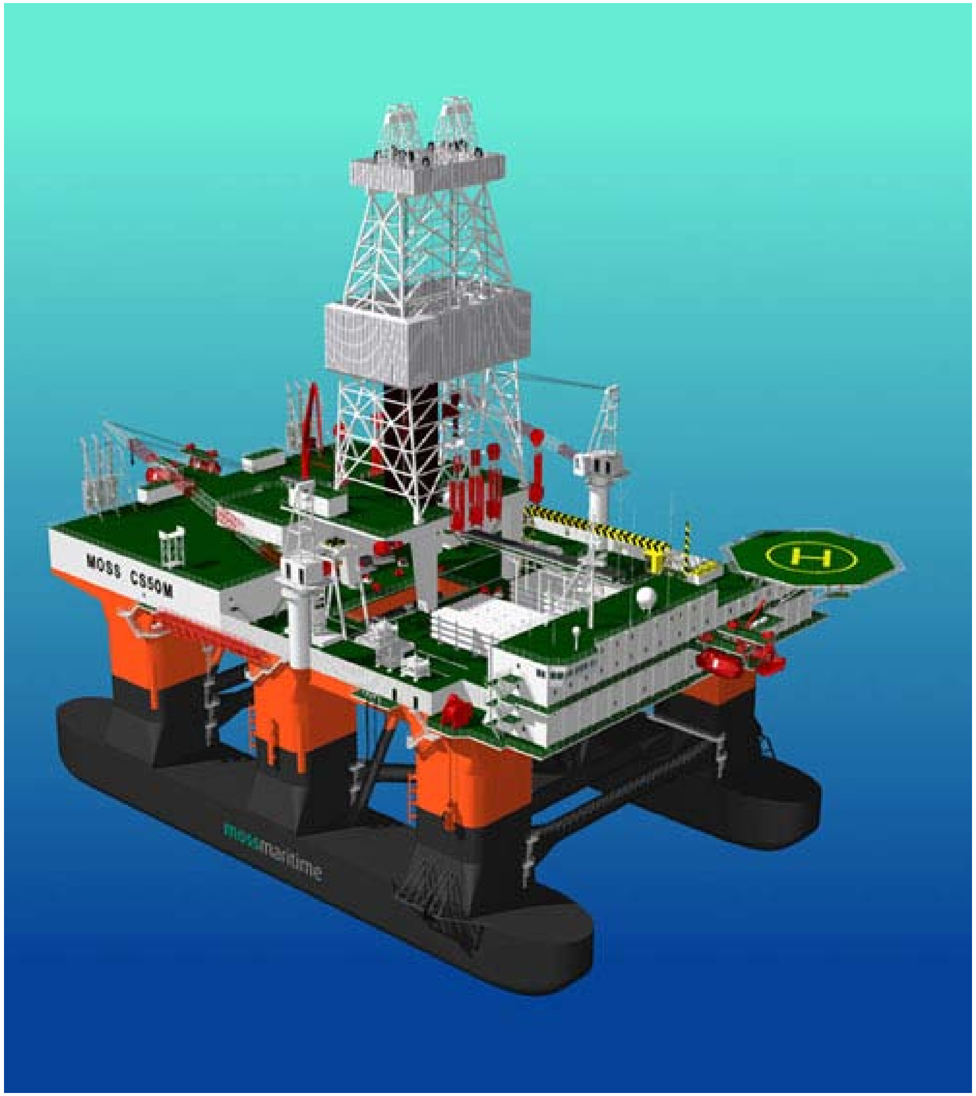

Fig. 7. A typical semi-submersible platform.

- Types of SSPs: Three main types,

❖ **Semi-submersible rigs:** It is a floating vessel that is supported primarily on large pontoon structures submerged below the sea surface. The operating decks are typically elevated 100 feet above the pontoons on large steel columns.

Anchoring: They are usually anchored to the seabed with six to twelve anchor chains, or kept in place by a dynamic positioning (DP) system, which is a computer controlled thruster system used to maintain station keeping.

Applications: Drilling, work-over operations, and as production platforms, depending on their equipment.

Modern semi-submersible rigs, with DP systems, have the capacity to operate in ultra deep water in excess of 5,000 feet.

Additional advantage: They are flexible concerning operating water depth and have the capacity to work in medium water and some shallow water fields.

❖ **Drill-ships:** It is a ship equipped with a drilling rig and station-keeping equipment such as anchor chains or a DP-system and thrusters.

They carry larger payloads than semi-submersible rigs and due to their mobility and ability to carry large amounts of drilling equipment, drill-ships are well suited to operate in remote areas.

Applicable depths: Operate in water depths ranging from approximately 200 feet to ultra deep water in excess of 5,000 feet, depending upon individual ship specification.

Requirement: A DP system to operate in ultra deep water.

❖ **Jack-up rigs:** It is a self-contained drilling rig and floating barge, fitted with long support legs that can be raised or lowered independently of each other.

The rig is towed onto location by a supply vessel with its legs elevated and the barge section floating on the water.

Upon arrival at the drilling location, the three legs are jacked down to the seabed, raising the entire barge and drilling structure slowly above water, to a predetermined height.

Applicable depths: Normally for operations in shallow waters down to 300 feet. Advanced modern jack-up rigs have longer legs and may operate in water depths down to 400 feet, thus entering a territory traditionally occupied by semi-submersible rigs.

Operating costs: Jack-up rigs have normally lower operating costs than semi-submersible rigs and drill-ships.

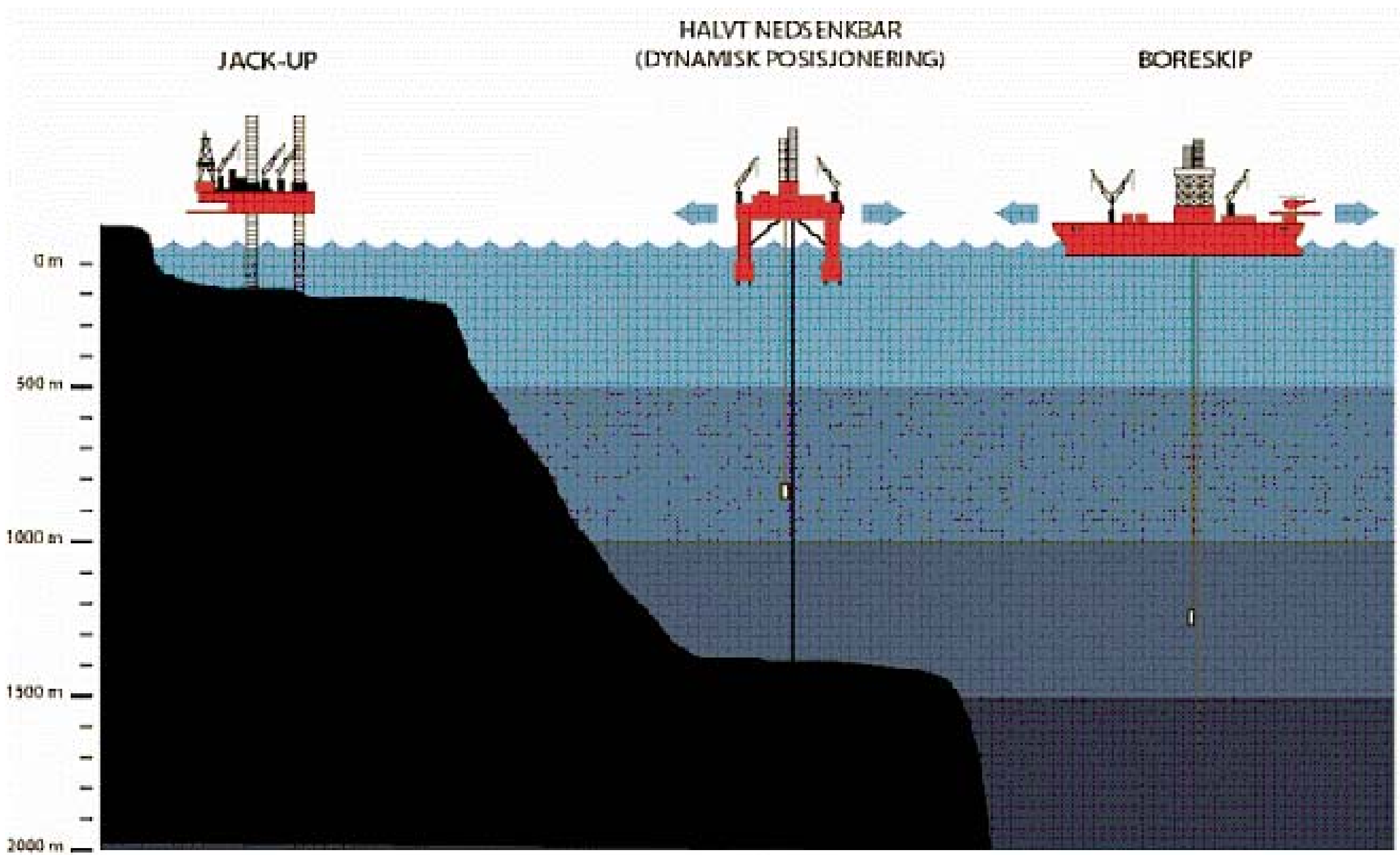

Fig. 8. Different applicable depths of semi-submersible platforms.

RECENT EXAMPLES: Thunder Horse is the largest moored semi-submersible oil platform in the world, located in 1,920m of water in the Mississippi Canyon Block, Thunder Horse oilfield, New Orleans, USA.

Construction cost: 1 billion $ US. Life span: 25 yrs,

Production capacity: 1 billion barrels of oil.

At its peak, it is expected to process 200 million cubic feet of natural gas and 250,000 barrels of oil per day.

Offshore platforms ……………………. Semi-submersible Platforms

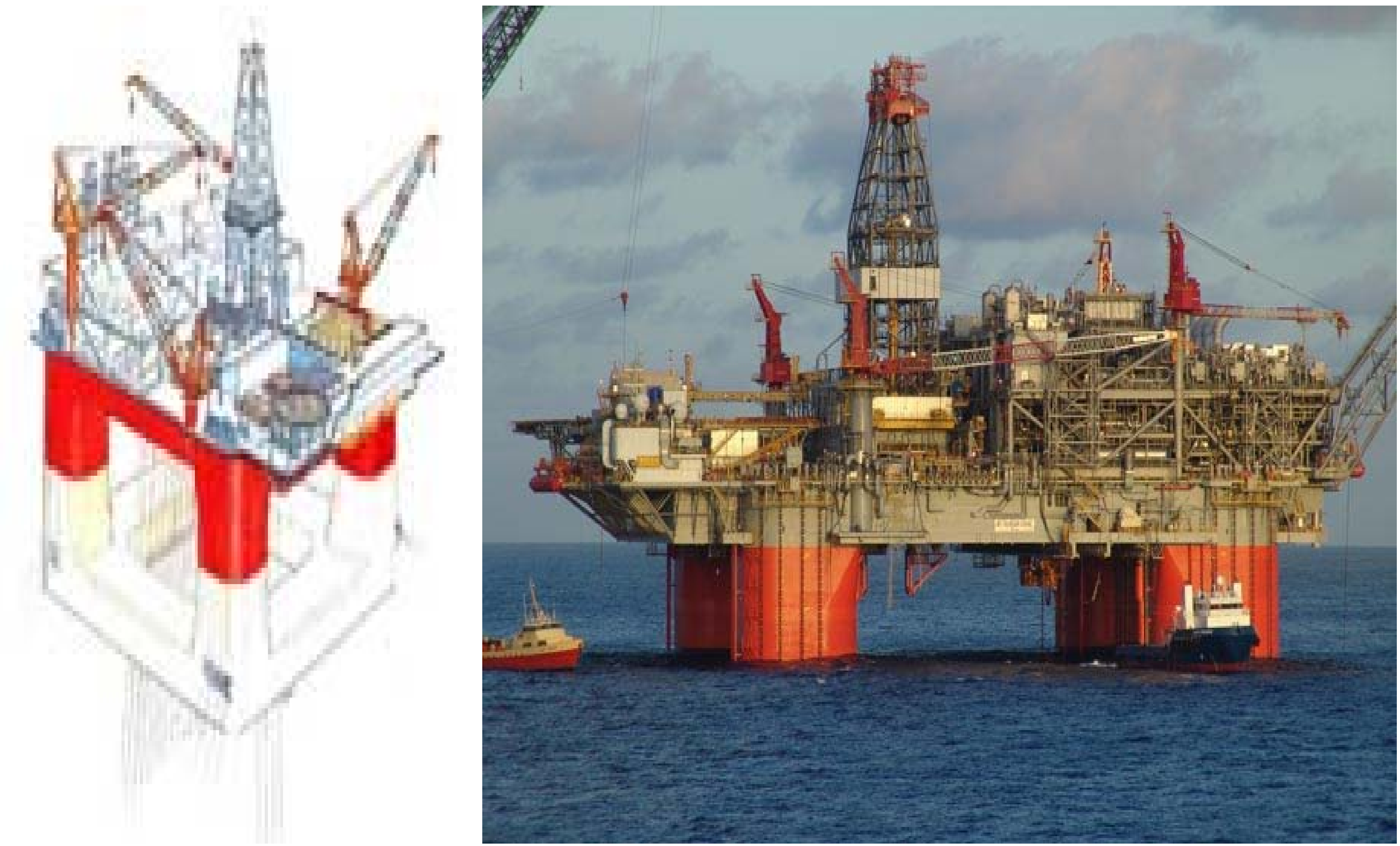

Fig. 9. A semi-submersible platform Thunder Horse, USA.

Fig. 10. A typical jack-up platform.

• **Brief description:** They are platforms that can be jacked up above the sea, by dint of legs than can be lowered like jacks.

• **Basic feature:** It is a type of barge that may stand still on the sea floor resting on a number of supporting columns. Supporting columns are usually moved up and down by a hydraulic system. The whole barge can also be jacked up when the supporting columns are touching the sea floor.

Applicable depths: Used in relatively low depths, are designed to move from place to place, and then anchor themselves by deploying the jack-like legs.

RECENT EXAMPLE: SELF ELEVATING PLATFORM JB-109/JB-110, MSC-2000, Make/Yard Labroy Marine Limited, Singapore, Main Dimensions: L = 55.5m, B = 32.2m, D = 5m, Draft max. = 3.6m, Leg length = 73.2m, [max. 80 metre], Leg diam. 3.00 metre, Spudcans 24.00m^2 each.

Fig. 11. A jack-up platform, Singapore.

Fig. 12. A typical drill ship.

- **Brief description:** It is a maritime vessel that has been fitted with drilling apparatus. In order to drill, a Marine Riser is lowered to the seabed with a Blow Out Preventer (BOP) at the bottom.

- **Objectives:** Used for exploratory drilling of new oil or gas wells in deep water but can also be used for scientific drilling. Built on a modified tanker hull and outfitted with a dynamic positioning system to maintain its position over the well.

- **Applicable depths:** Normally able to drill up to 5000m. Recent, modern ones can up to 7000m.

- The function of DSs can also be performed by Semi-submersibles, jackup barges, barges, or platform rigs.

RECENT EXAMPLES: 210m IODP vessel D/V Chikyu, Japan, that can drill 7000m below the sea bed.

Fig. 13. A drill ship, Chikyu, Japan.

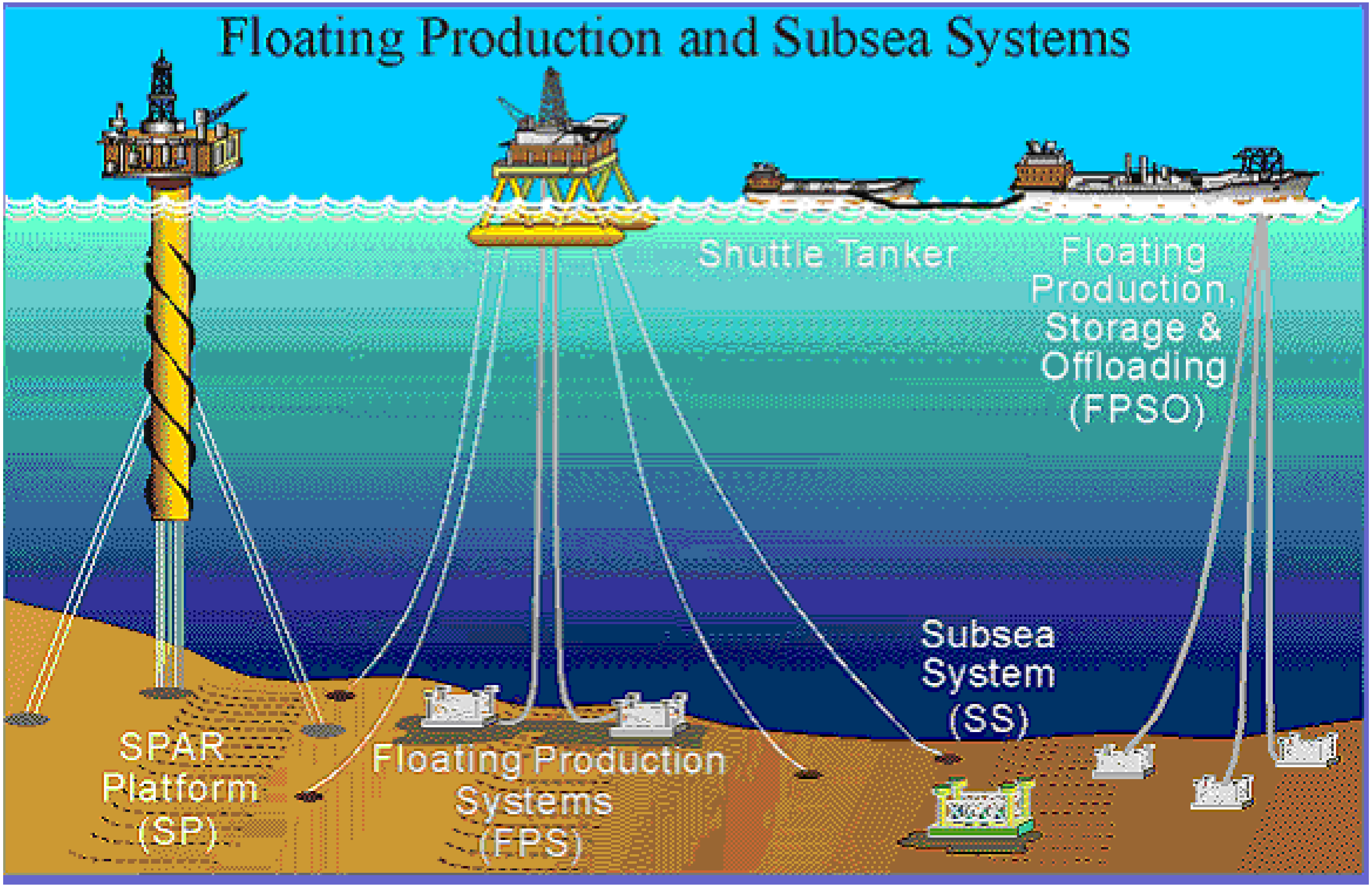

Fig. 14. Some typical floating production systems.

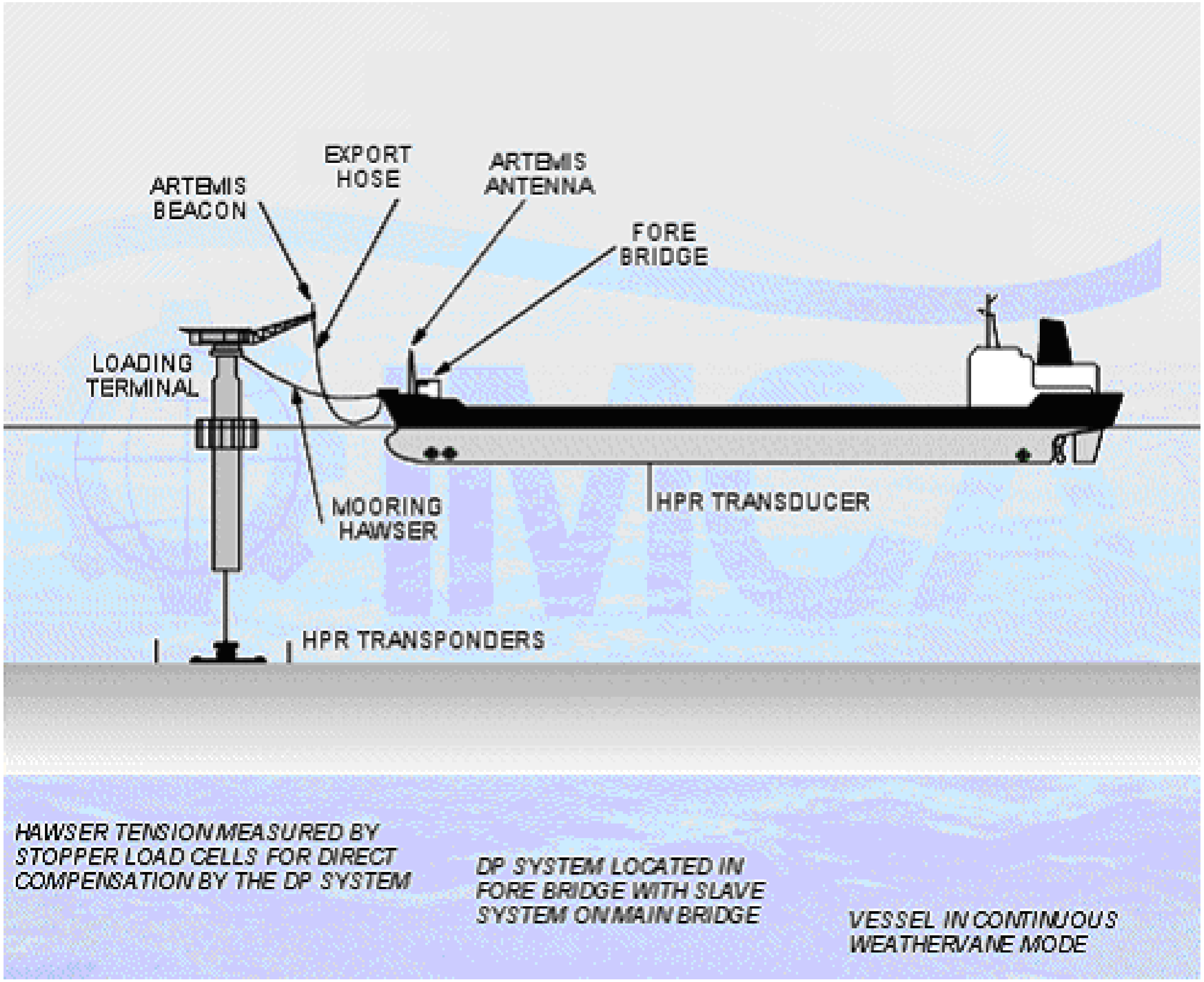

Fig. 15. A typical shuttle tanker (floating production system).

- **Brief description:** They are large ships equipped with processing facilities and moored to a location for a long period.

- **Types of FPSs:** FPSO (floating production, storage, and offloading system), FSO (floating storage and offloading system), and FSU (floating storage unit).

- **Note that these ships do not actually drill for oil or gas.***
- FPSO is also called a "unit" and a "system“ is a type of floating tank system used by the offshore oil and gas industry and designed to take all of the oil or gas produced from nearby platforms, process it, and store it.

- Then from FPSO the oil or gas is offloaded onto waiting tankers, or sent through a pipeline.

- A Floating storage and offloading unit is a similar system, but without the possibility to do any processing of the oil or gas.

- **Basic advantages:** FPSOs are effective in remote or deepwater locations where seabed pipelines are not cost effective. FPSOs eliminate the need to lay expensive long-distance pipelines from the oil well to an onshore terminal.

- FPSOs are economical in smaller oil fields which can be exhausted in a few years and do not justify the expense of installing a fixed oil platform. Once the field is depleted, the FPSO can be moved to a new location.

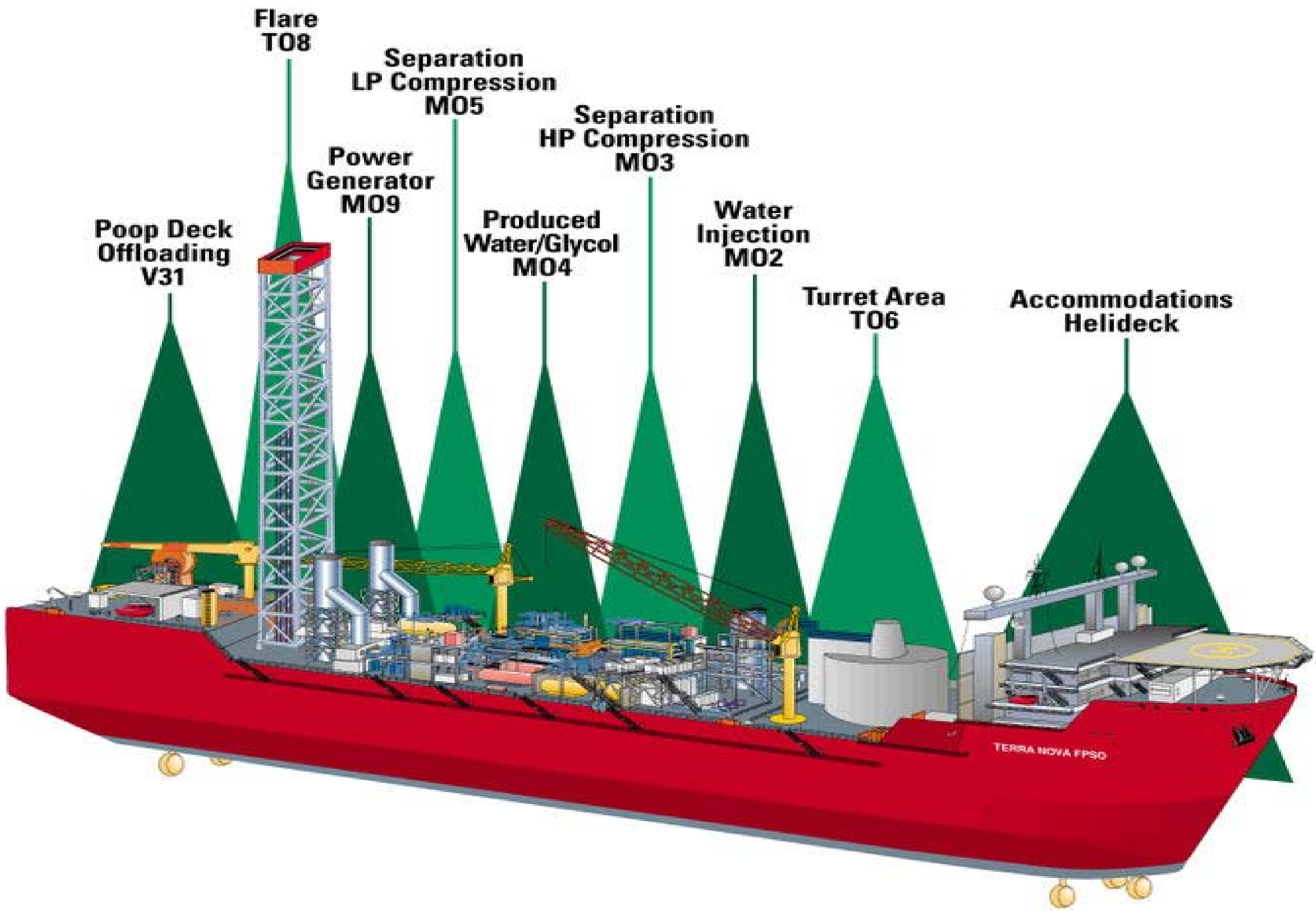

Fig. 16. Schematic of a typical floating production system.

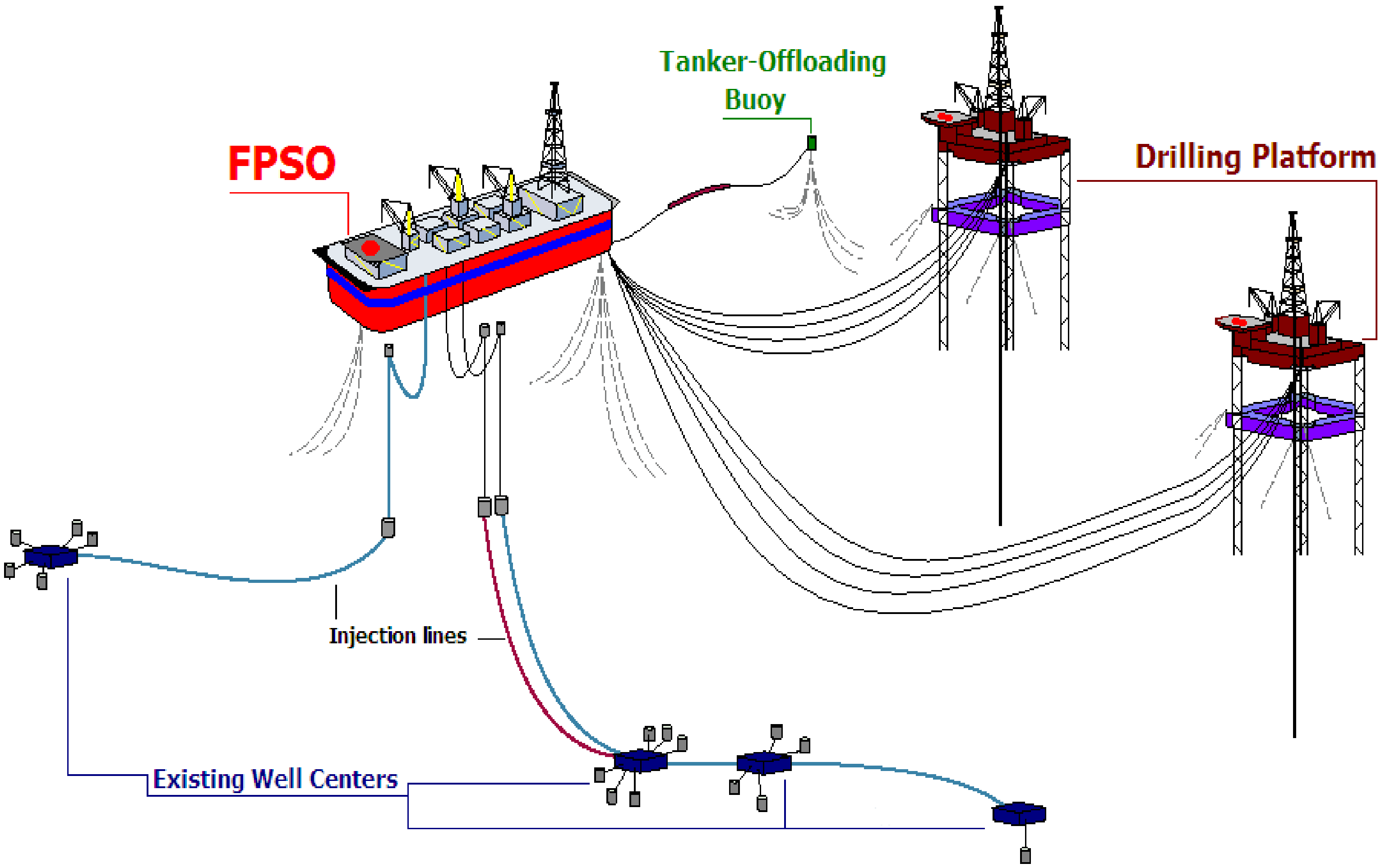

Fig. 17. Functional schematic of a typical FPSO.

RECENT EXAMPLES: FPSO vessel MODEC Venture II. The FPSO is installed in 156m of water and is capable of processing 100,000bopd. The FPSO was converted from the 140,000 dwt double-hulled Suezmax tanker Fairway.

Fig. 18. A FPSO, MODEC V II.

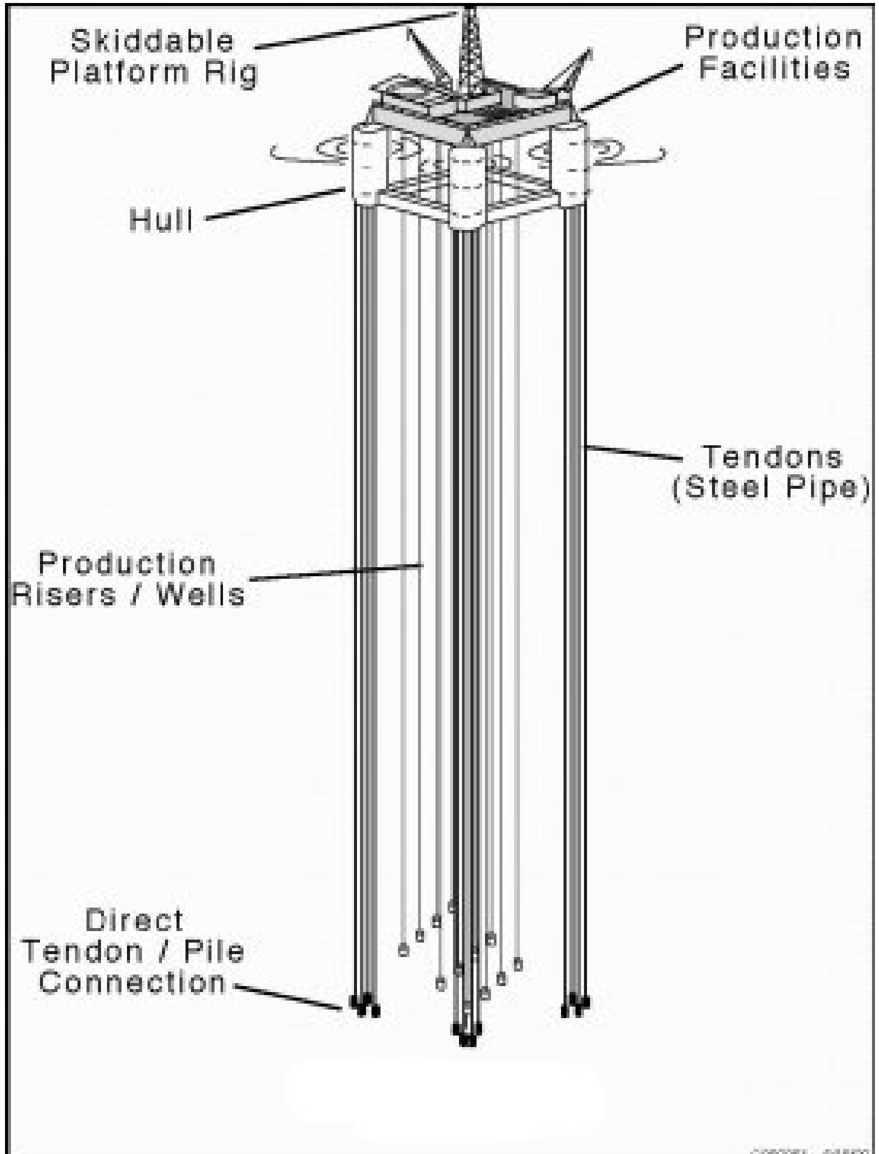

Fig. 19. Schematic of a typical tension-leg platform.

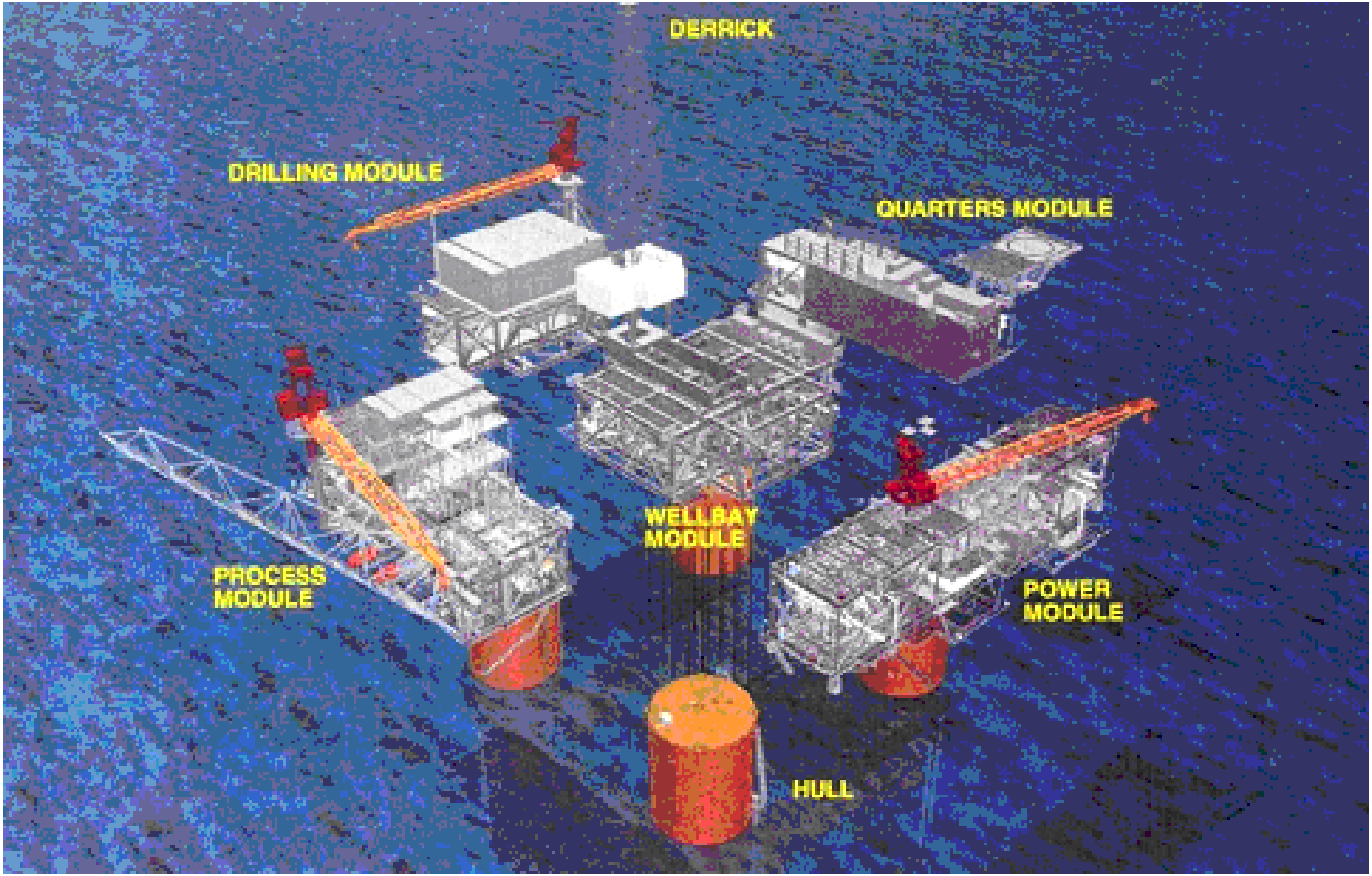

Fig. 20. Functional schematic of a typical TLP.

- **Brief description:** TLPs consist of floating rigs tethered to the seabed in a manner that eliminates most vertical movement of the structure.

- **Applicable depths:** Used in water depths up to about 2,000m.

- **Types:** Conventional TLP - 4-column design which looks similar to a semi-submersible. They are relatively low cost, used in water depths between 200 and 1,100 m.

- **Additional use:** Mini TLPs can also be used as utility, satellite or early production platforms for larger deepwater discoveries.

- **Mooring:** Permanently moored by means of tethers or tendons grouped at each of the structure's corners. A group of tethers is called a tension leg.

- **Important design feature:** Design of the tethers is done for relatively high axial stiffness (low elasticity), to eliminate virtually all vertical motion of the platform.

This allows the platform to have the production wellheads on deck (connected directly to the subsea wells by rigid risers), instead of on the seafloor. This makes for a cheaper well completion and gives better control over the production from the oil or gas reservoir.

RECENT EXAMPLES: Mars Tension Leg Platform at 2,940 feet of water, Gulf of Mexico, USA. It is designed with intelligent completion equipment; the first vertical, open-hole gravel pack; and the first use of 55 percent formic acid.

Fig. 21. A tension-leg platform, Mars, TLP, USA.

Fig. 22. A tension-leg platform, Mars, TLP, USA (large view).

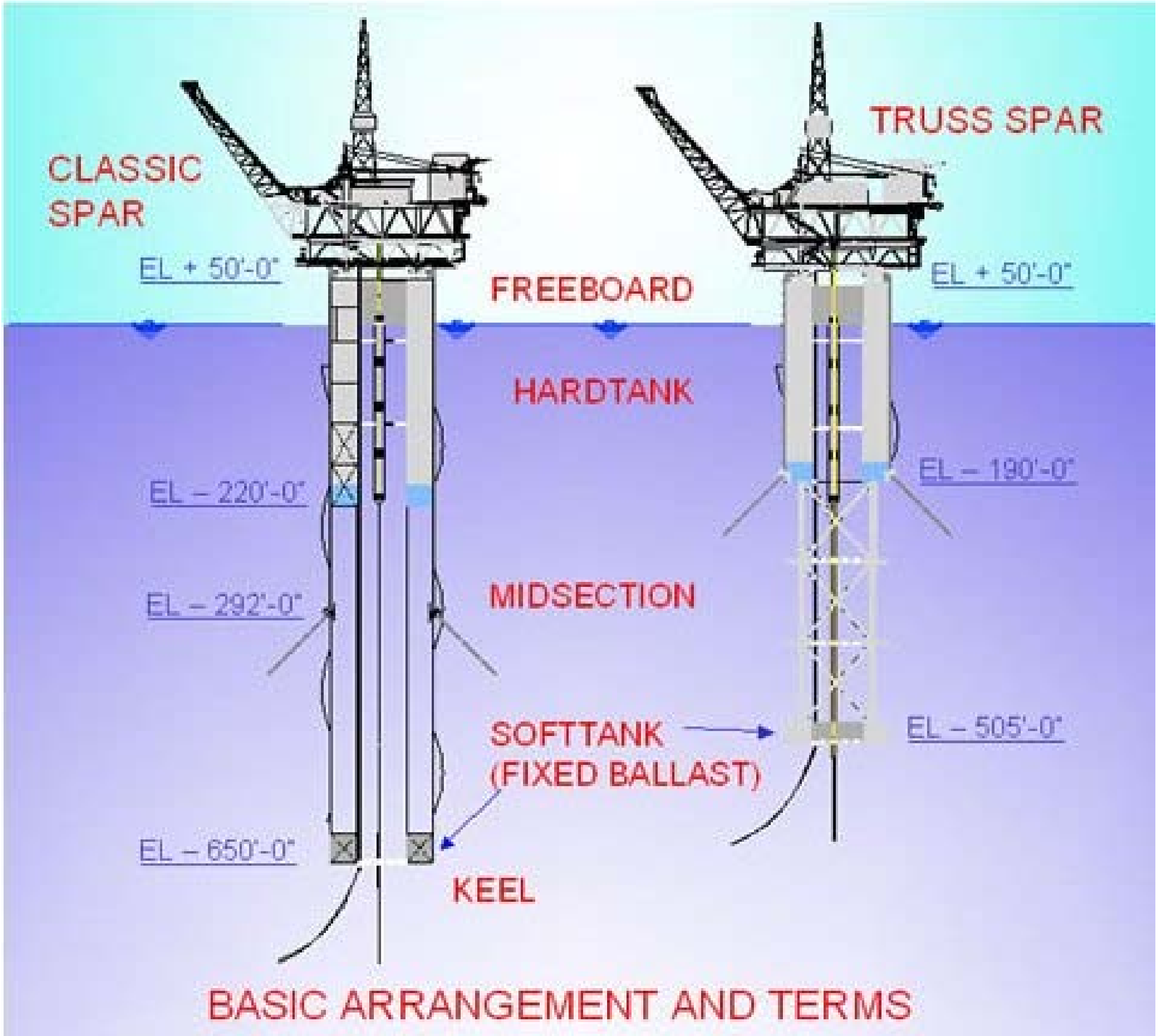

Fig. 23. Schematic of a typical SPAR platform.

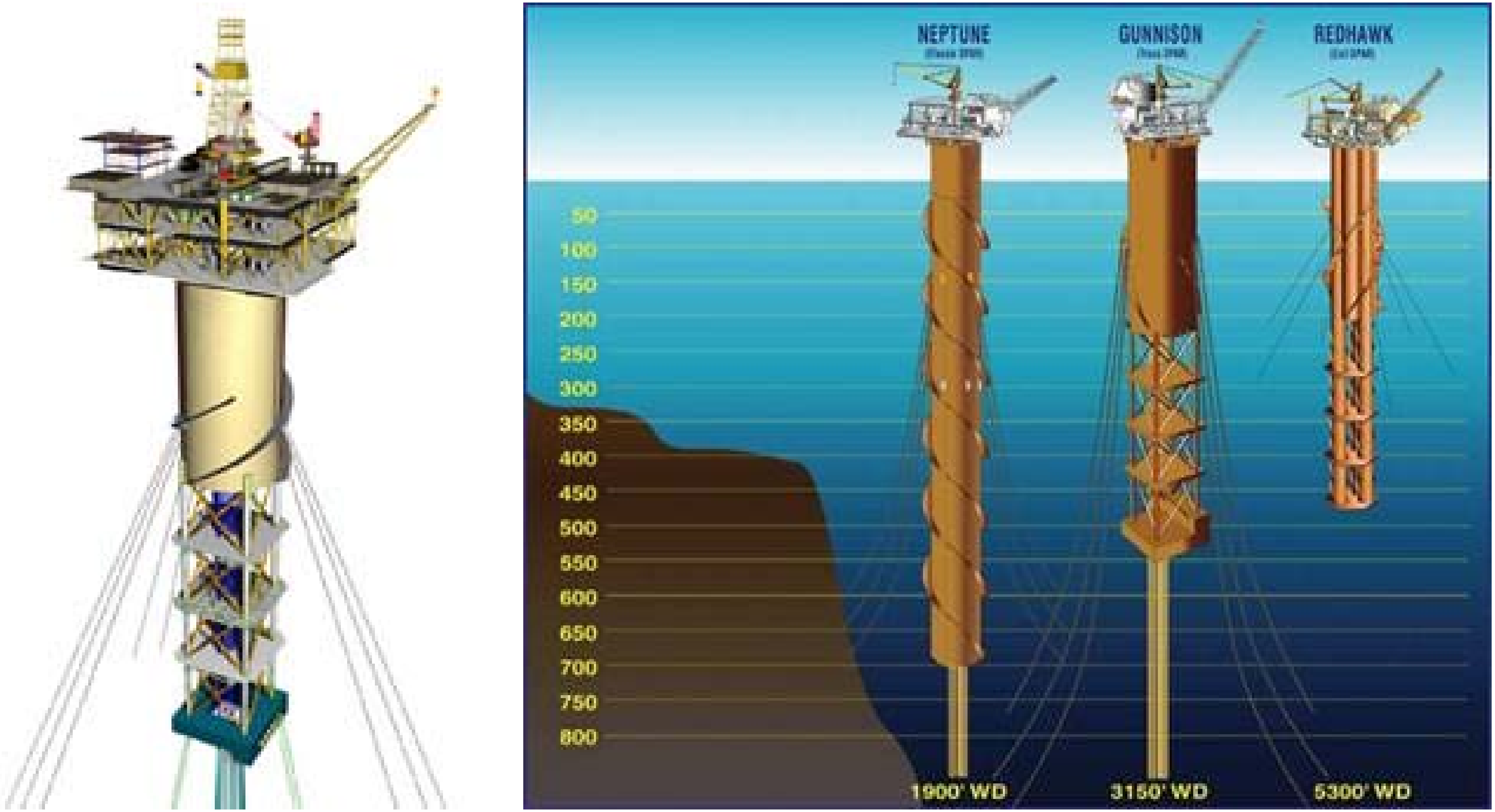

Fig. 24. Depth functional schematic of typical SPAR platforms.

- **Brief description:** They are moored to the seabed like the TLP, but whereas the TLP has vertical tension tethers the SPAR has more conventional mooring lines.

- **Types:** Three configurations: Conventional SPAR - one-piece cylindrical hull; Truss SPAR - where the midsection is composed of truss elements connecting the upper buoyant hull (called a hard tank) with the bottom soft tank containing permanent ballast; and Cell SPAR - which is built from multiple vertical cylinders.

- **Basic advantages:** SPAR is more economical to build for small and medium sized rigs than the TLP, and has more inherent stability than a TLP.

- **Basic advantages:**

  - Since it has a large counterweight at the bottom and does not depend on the mooring to hold it upright, it has good stability.

  - It also has the ability, by use of chain-jacks attached to the mooring lines, to move horizontally over the oil field.

- **Technical feature:** SPAR is normally designed by converting a FSOs.

RECENT EXAMPLES: Genesis SPAR Platform, New Orleans, Green Canyon, USA at water depth of 2,500ft to 3,000ft. Production facility is moored in 2,600ft of water.

Fig. 25. Genesis SPAR Platform, New Orleans, USA.

Fig. 26. A typical unmanned installation.

Offshore platforms ………….…………….. Unmanned installations

- **Brief description:** It is a type of offshore facility that is designed to be operated remotely without the constant presence of personnel.

- **Important features:** Small size, often consisting of just a well bay with a helipad on top. They are often a compromise of providing the convenience of surface wellheads, which are easier to build and maintain, while avoiding the high operating costs of a full production platform.

- **Applicable depths:** Used only in shallower water, where constructing many small UIs is a relatively easy and cheap option as compared to the cost of using subsea wells.

RECENT EXAMPLES: Sleipner Unmanned Installation B (Øyvind Hagen, Statoil), Norway.

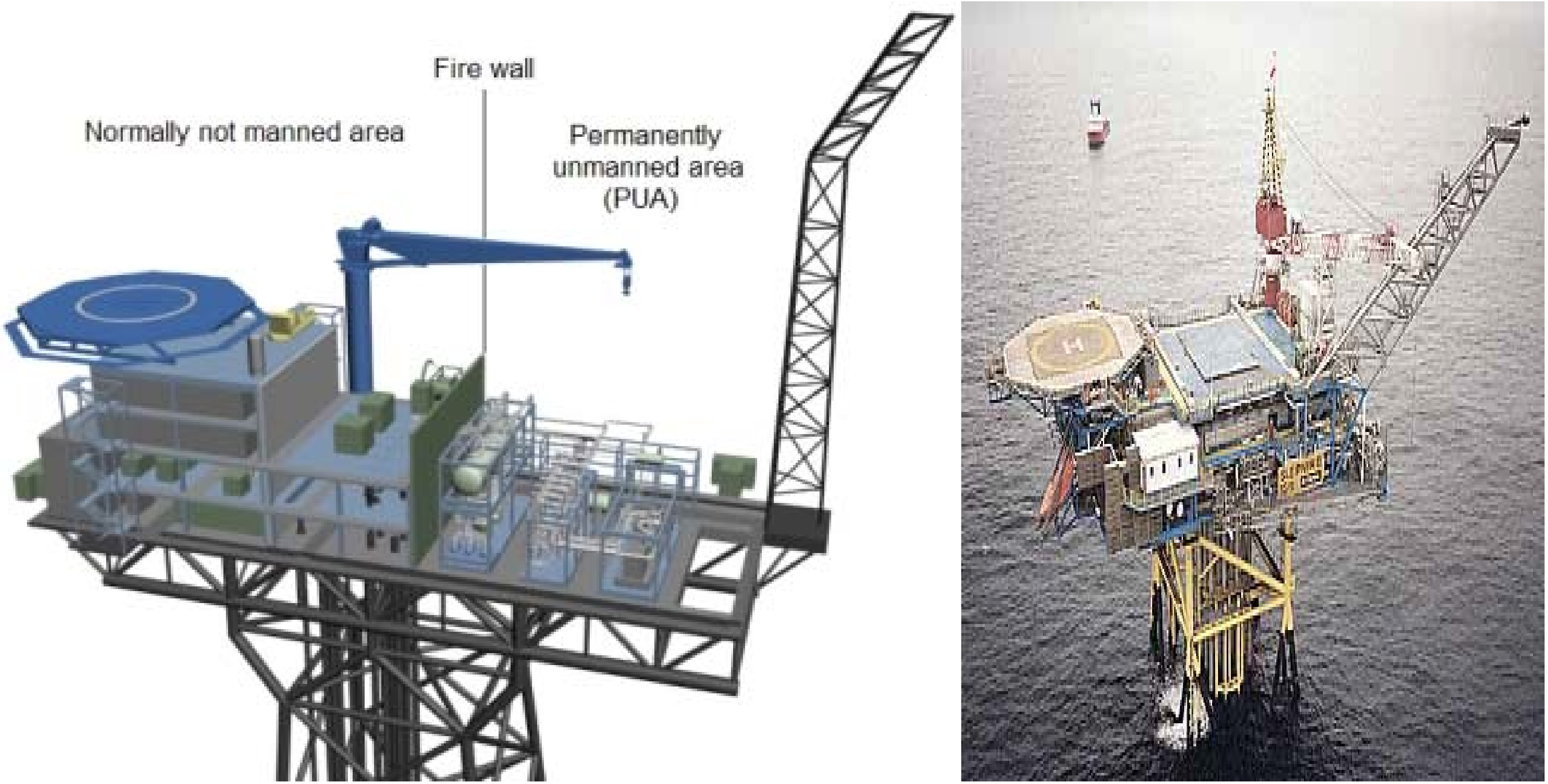

Fig. 27. Sleipner Unmanned Installation, Norway.

- Nature of offshore operations (e.g. extraction of volatile substances sometimes under extreme pressure in a hostile environment) carry risk for human crew.

- Practice of mandatory accommodations on separate rigs, away from those used for extraction should be enforced.

- Also, recently because of the importance of gas/oil platforms to the economy, platforms are believed to be potential terrorist targets.

- Agencies and military units responsible for maritime counterterrorism better be trained for platform raids.

- Decommissioning of offshore platform is very expansive, and without proper dismantling the left over offshore platforms are damaging to the environment and ecology.

For UK the cost of removing all platform rig structures entirely was estimated in 1995 at $345 billion, and the cost of removing all structures including pipelines ("clean sea" approach) at $621 billion.

- Leaching of heavy metals that accumulate in buoyancy tanks into water; and risks associated with their disposal are being considered severe threat to the ecology and environment.

- There has been concern expressed at the practice of partially demolishing offshore rigs to the point that ships can traverse across their site; there have been instances of fishery vessels snagging nets on the remaining structures.

- Recent trend is towards retaining oil platforms for different purposes e.g. as artificial reefs, re-newable energy centers, etc. instead of dismantling them.