Deep Water Field Development Concepts for Eastern Offshore, India

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Outline

- Bathymetry
- Environment
- Conventional concepts
- Floating System components
- Spar an advantage ?
- Fabrication & Installation
- Research at IIT Madras

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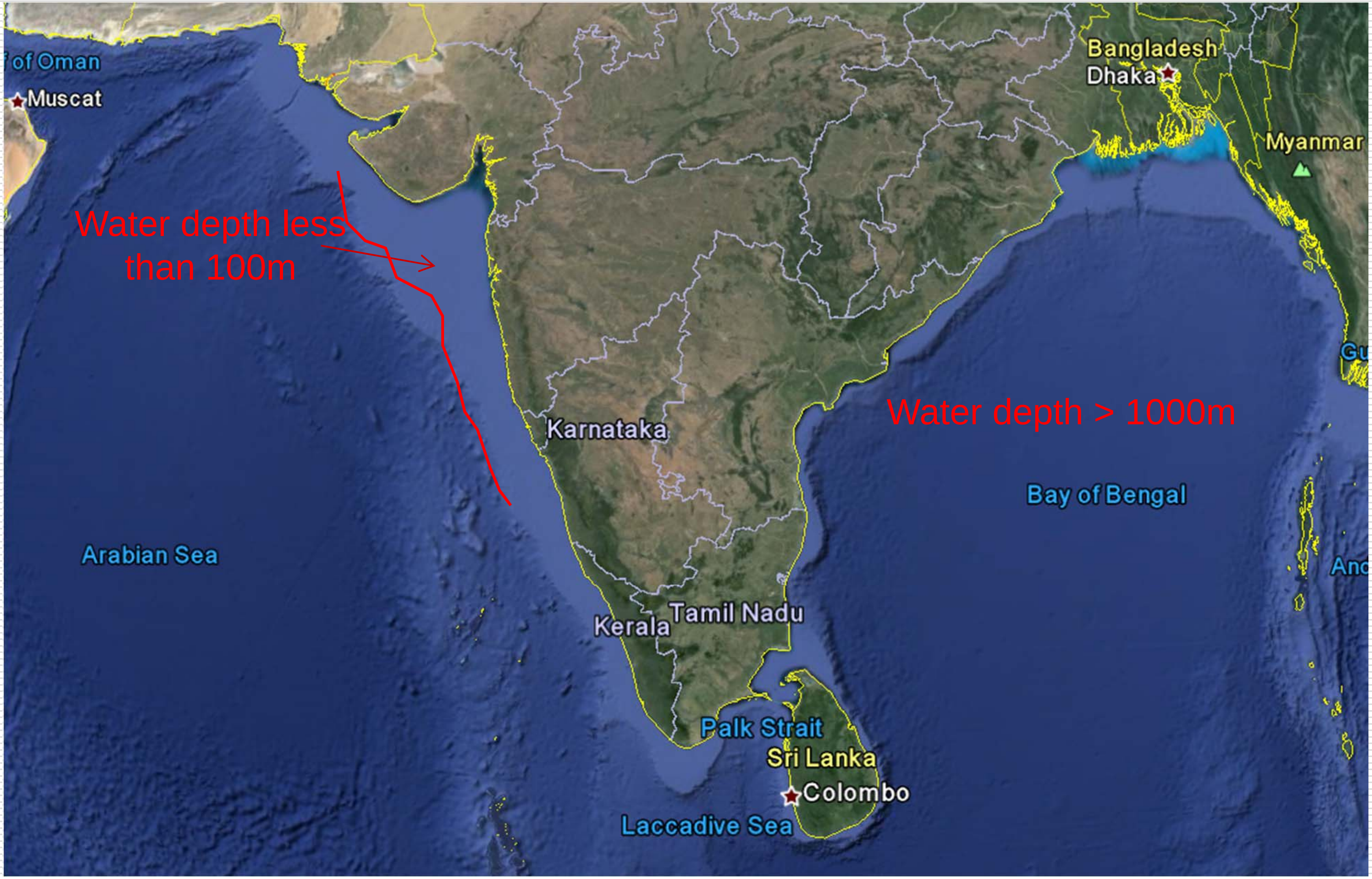
Seabed Profile in East and West Coast



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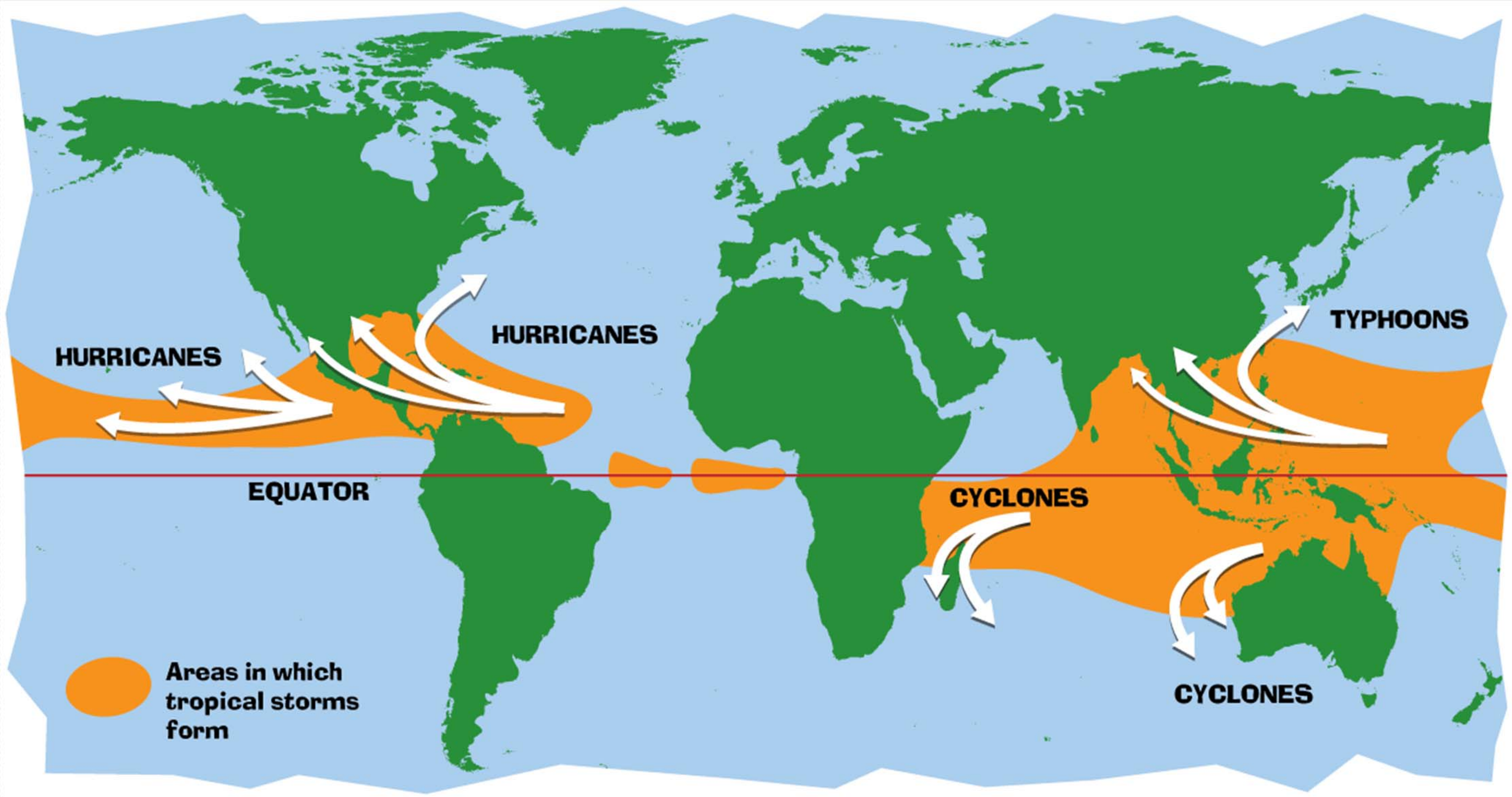
Areas in which tropical storms form



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CYCLONES AND STORMS

Cyclonic storms are very common in the east coast.

Table shows the crossing of cyclones in the southern east coast including the recent one crossed in Orissa.

The storm surge in many of the cyclones exceed 3m and the wind speed has crossed 200 km/hour in many occasions.

It can be observed from the above table that the vulnerability of platforms to cyclonic storms is high.

S.No	Year	Month	Place of Crossing	Max Intensity
1	1960	Nov.	Near Chennai	CS
2	1962	May	Near Cuddalore	CS
3	1963	Oct.	Bet. Pondicherry and Cuddalore	SCS
4	1964	Nov.	South of Chennai	SCS
5	1966	Apr.-may	Near Cuddalore	SCS
6	1966	Nov	South of Chennai	SCS
7	1966	Nov	South of Chennai	SCS
8	1967	Dec.	Near Nagapattinam	SCS
9	1969	Oct.	South of Chennai	CS
10	1972	Dec.	North of Cuddalore	SCS
11	1977	Nov.	South of Nagapattinam	SCS
12	1984	Nov/Dec.	North Karaikal	SCS
13	1991	Nov.	Near Karaikal	CS
14	1993	Dec.	Near Karaikal	SCS
15	1994	Oct	Over Chennai	SCS
16	1996	Nov/Dec	Near Chennai	SCS
17	2000	November	Bet. Chennai & Nagapattinam	SCS
18	2001	October	Near Chennai	CS
19	2003	December	Near Chennai	SCS
20	2005	October	Near Chennai	D
21	2006	October	Near Chennai	CS
22	2007	October	Bet. Chennai & Nagapattinam	D
23	2008	November	Bet. Chennai & Nagapattinam	CS
24	2009	December	Near Chennai	CS
25	2011	December	Near Cuddalore	CS
26	2012	October	Near Pondicherry	CS
27	2013	October	Near Gopalpur	SCS

Legend

D : Depression
CS : Cyclonic storm
SCS : Severe Cyclonic Storm

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OFFSHORE ENVIRONMENT AND CHALLENGES

- Sea waves can reach as much as 30m in deep water condition (depth > 500m)
- Wind velocity can reach as much as 260 km/hour during cyclone

Environment	Parameter	Return period	
Sea state	Maximum wave height	100 year	1 year
		30.9 m	7.9 m
	Wave period	14 s	8.3 s

Hence the system shall have provision to protect risers while the plant can be temporarily relocated during storms.

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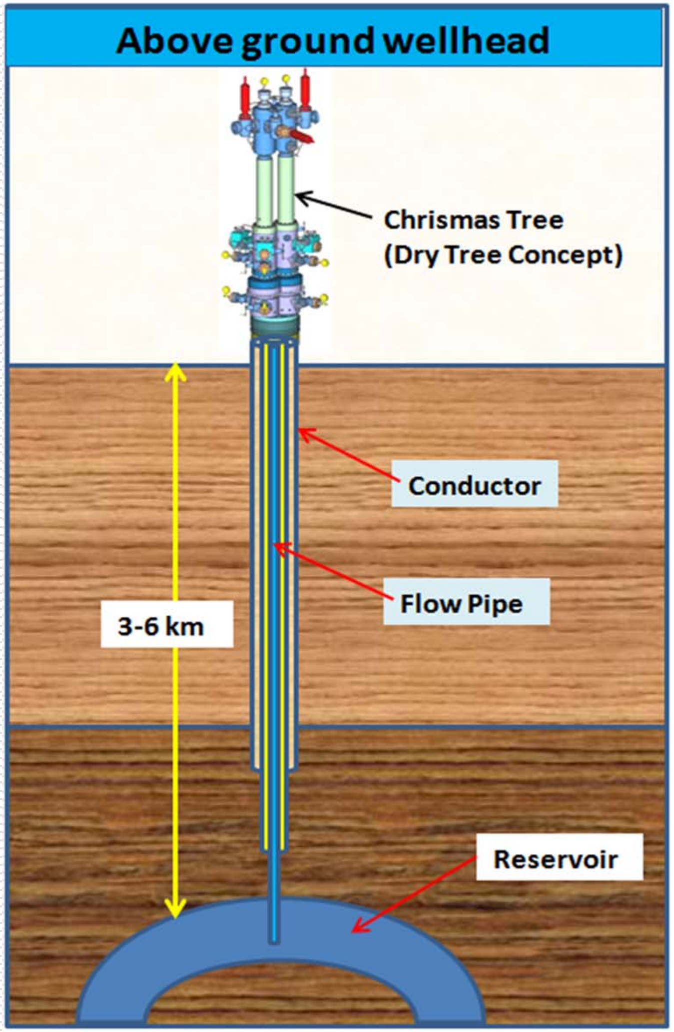
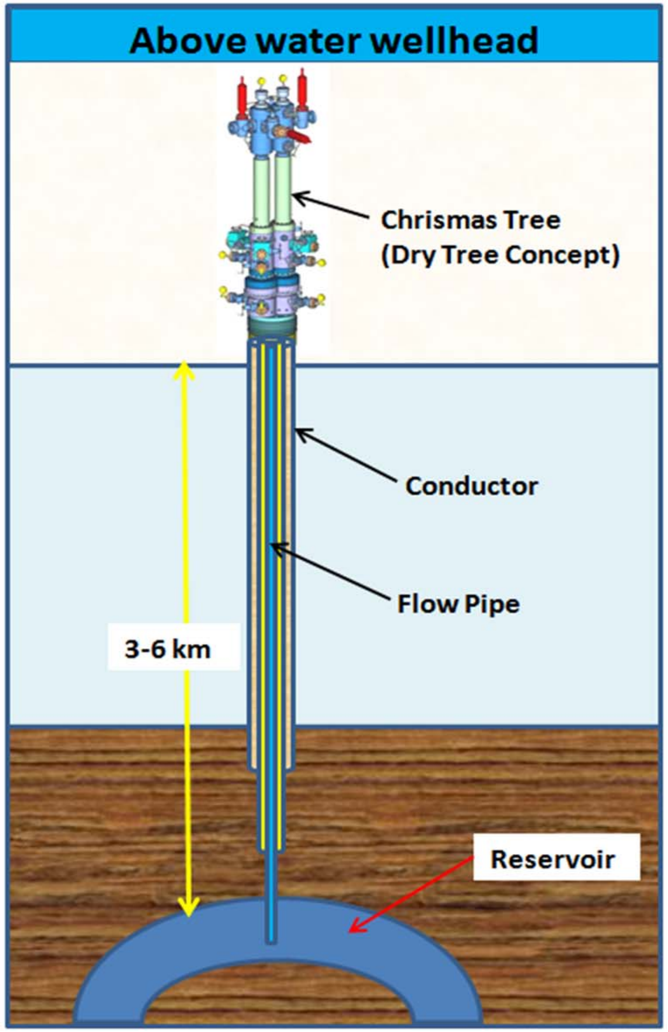
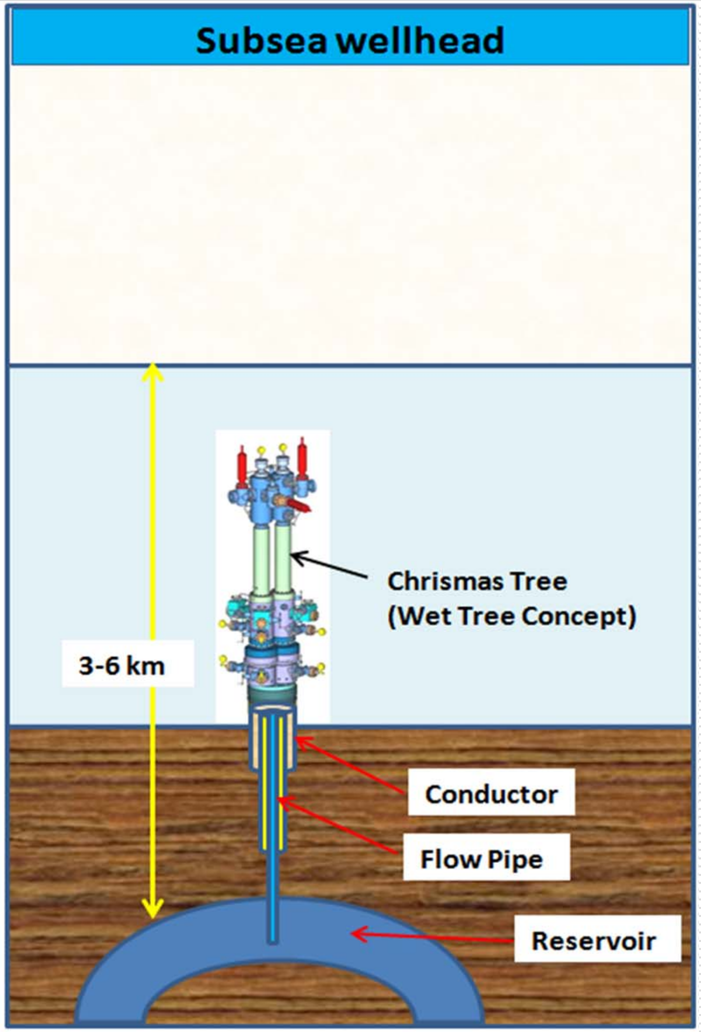
DRY AND WET TREE CONCEPTS







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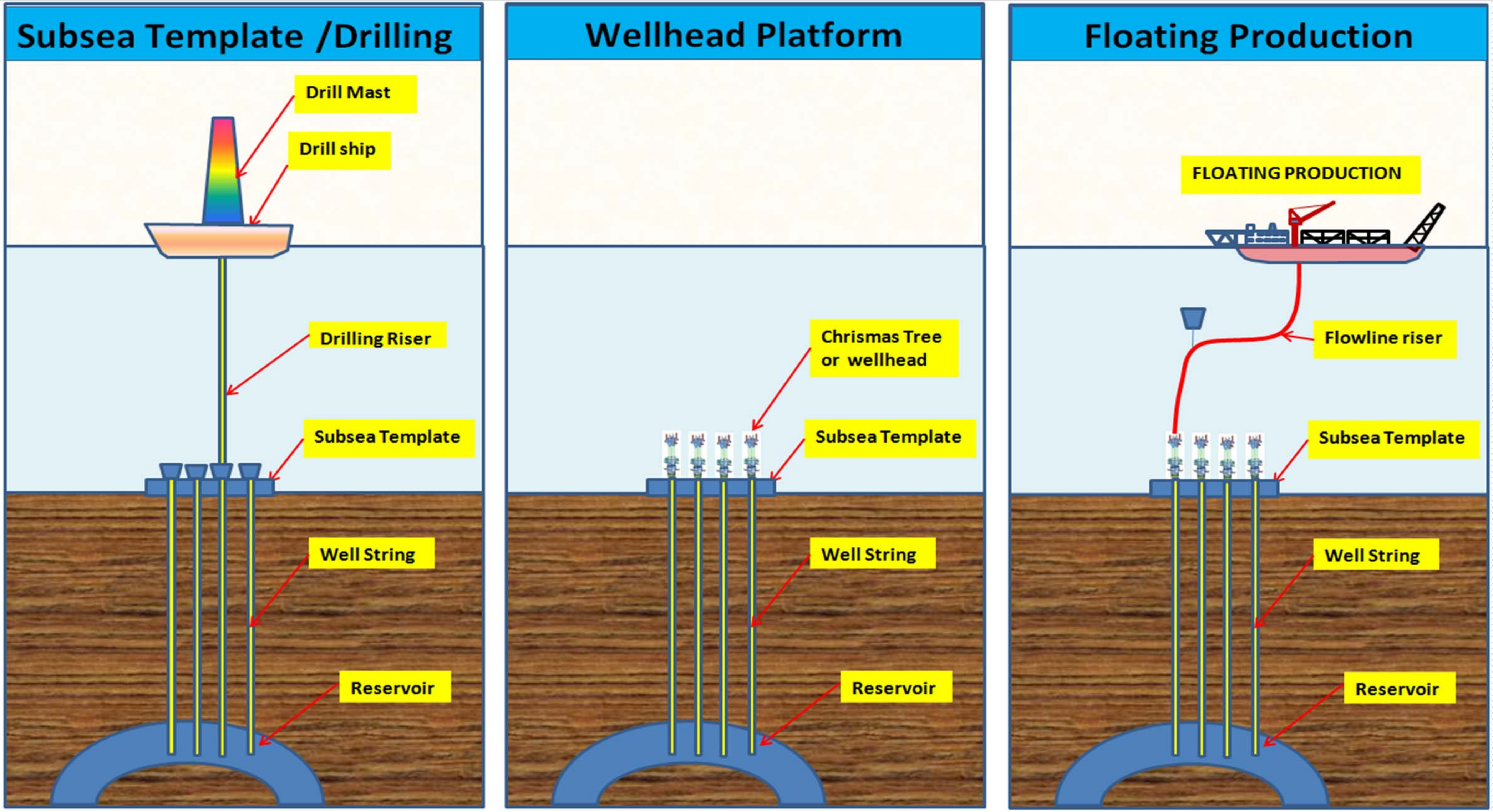
Concepts for Deep Water Field Development – Eastern Offshore



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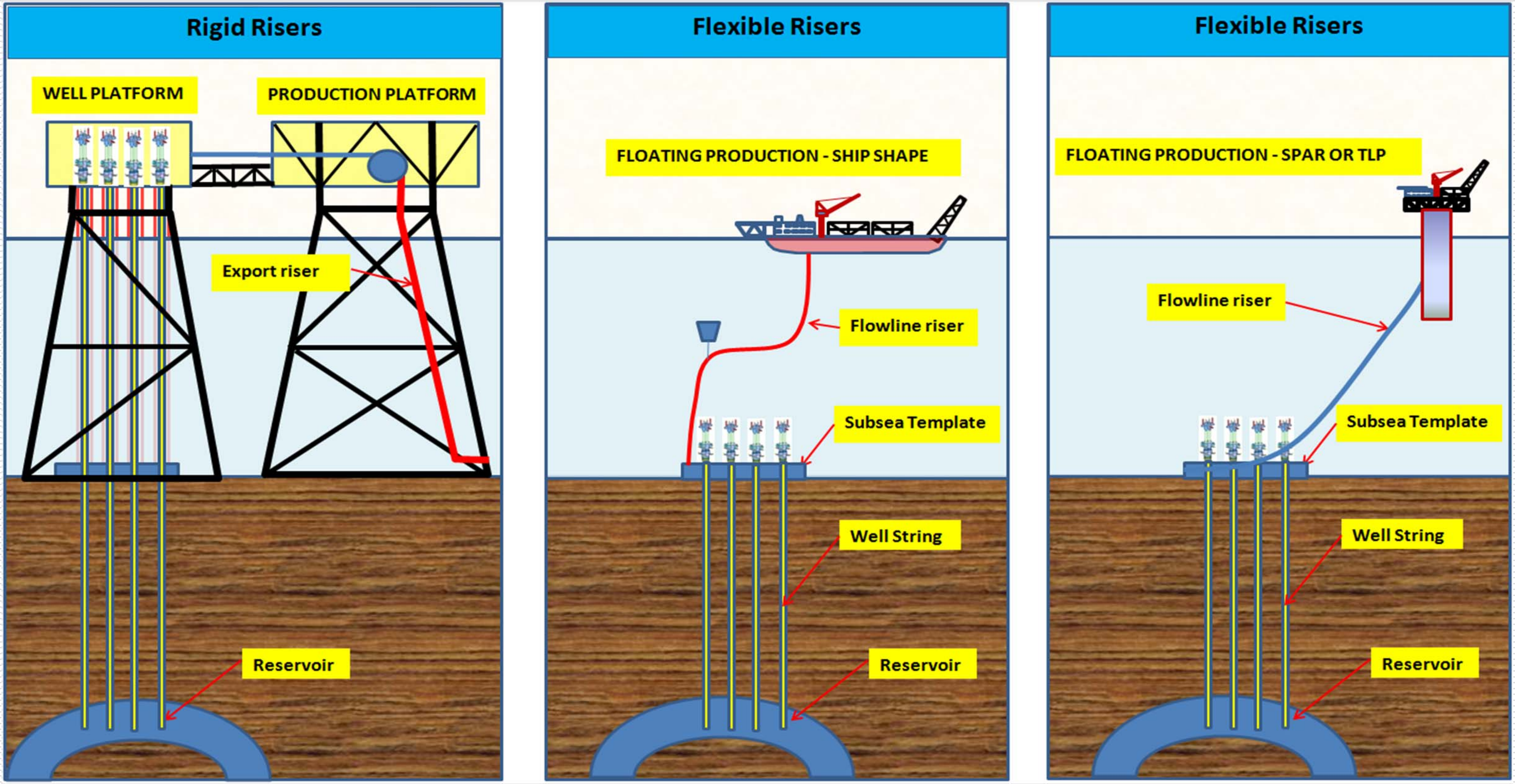
Risers



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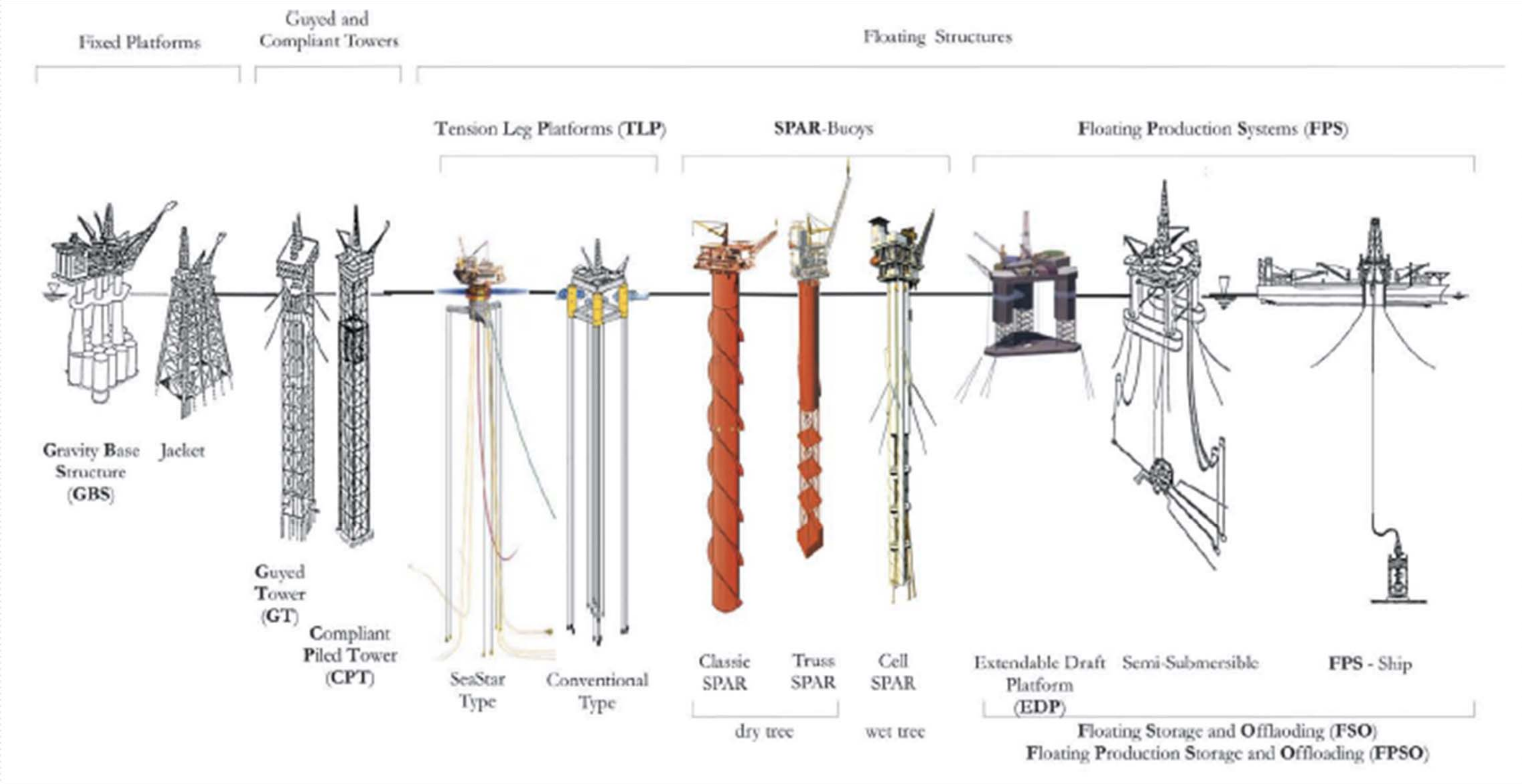
Progression of offshore platforms from shallow water to deep water



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Shallow water

- Water depth ranges from 20m – 200m.
- Drilling operation is by jack up rigs.
- Bottom Fixed structures.
- Dry Tree Concepts
- Geotechnical Parameters govern the type of substructure.
- Usually split in to platforms based on functional requirements such as Well, Process, Living etc.
- Storage is not possible
- Relocation is not possible

Deep water

- Water depth ranges from 200m-1500m.
- Drilling operation is by drill ships and semisubmersible
- Floating structures.
- Not depends on soil conditions
- Can support large size topsides with combined functions.
- Storage is possible and useful method for marginal fields where offloading is not continuous
- Possible to relocate to safe areas in case of extreme environmental conditions.

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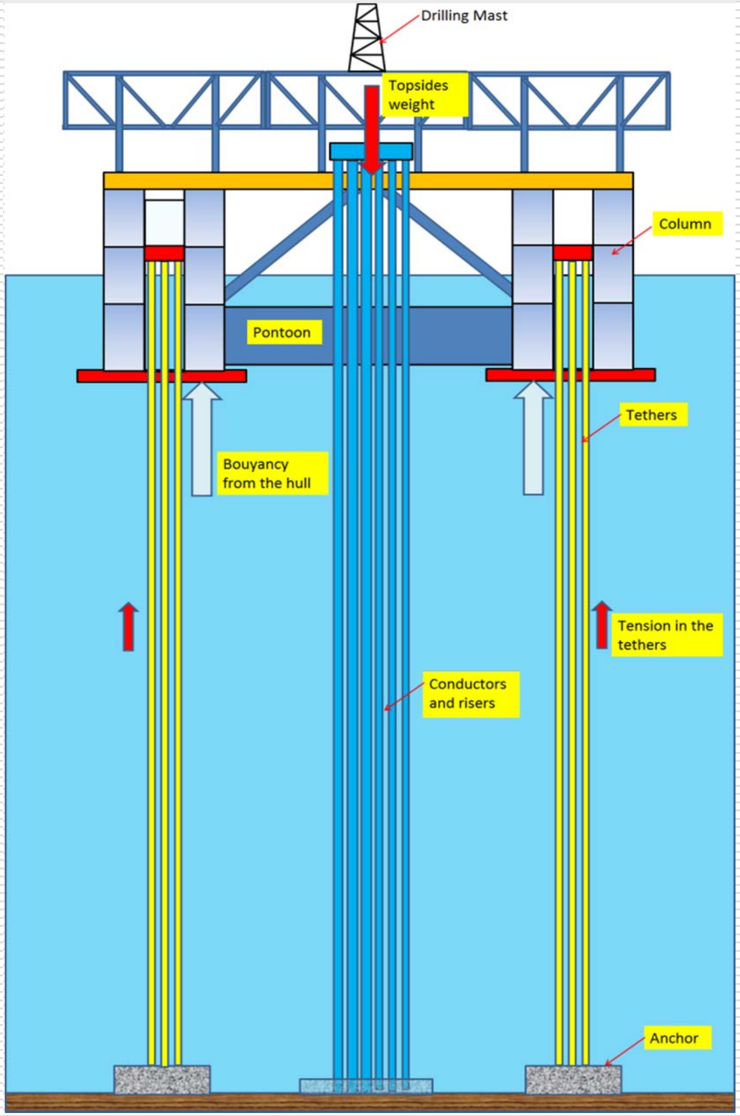
SUITABLITY OF FLOATING SYSTEM

- ❑ Hull Form Selection
  - Tension Leg Platform
  - Semi-submersible
  - Spar
- ❑ Hydrodynamic Response
  - ❑ Require Considerable work in the Laboratory Wave Basin to simulate the response
- ❑ Mooring Systems
  - ❑ Suitable Mooring system shall be selected based on prevailing environment
- ❑ Riser Systems
  - ❑ Suitable Riser system to accommodate the floater motion

TENSION LEG PLATFORMS



- **Tension Leg Platform (TLP)** is a floating hull, usually supported on four columns and pontoons.

- The columns are connected to hull through vertical tethers and anchored to seabed with a pretension. The pretension is achieved from the excess buoyancy.

- The gravity loads from the hull and the topsides are supported by buoyancy from the hull similar to the ships.

- TLPs are very common for deep water applications for drilling and production in excess of 1000m water depth.

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TENSION LEG PLATFORMS



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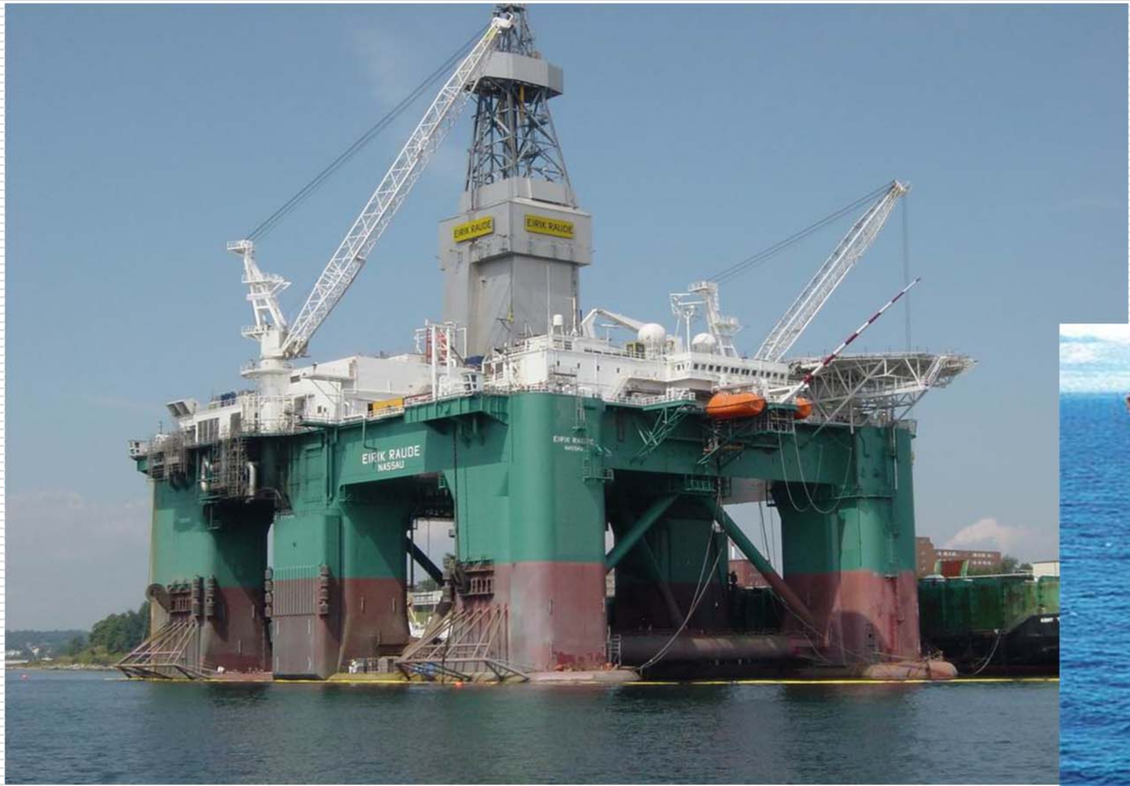
Semi-submersibles



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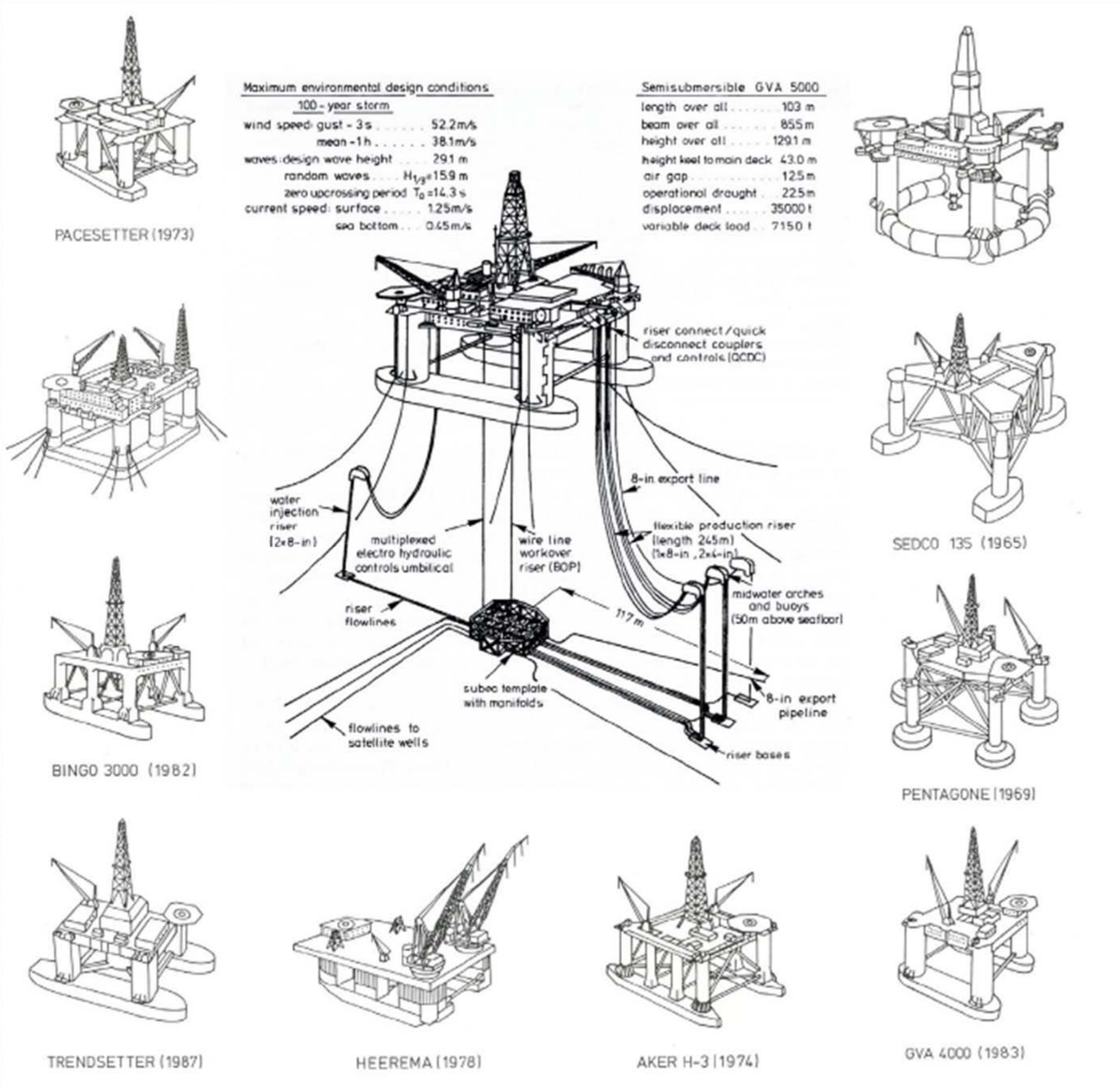
Semisubmersibles

- Semi-submersible consists of a deck, multiple columns and pontoons. They are column stabilized units.
- The stability of the semisubmersible is achieved by its water plane area.
- The hull is anchored to the sea bed by **spread mooring**.
- Semisubmersibles are used for deep water applications for **drilling and production**



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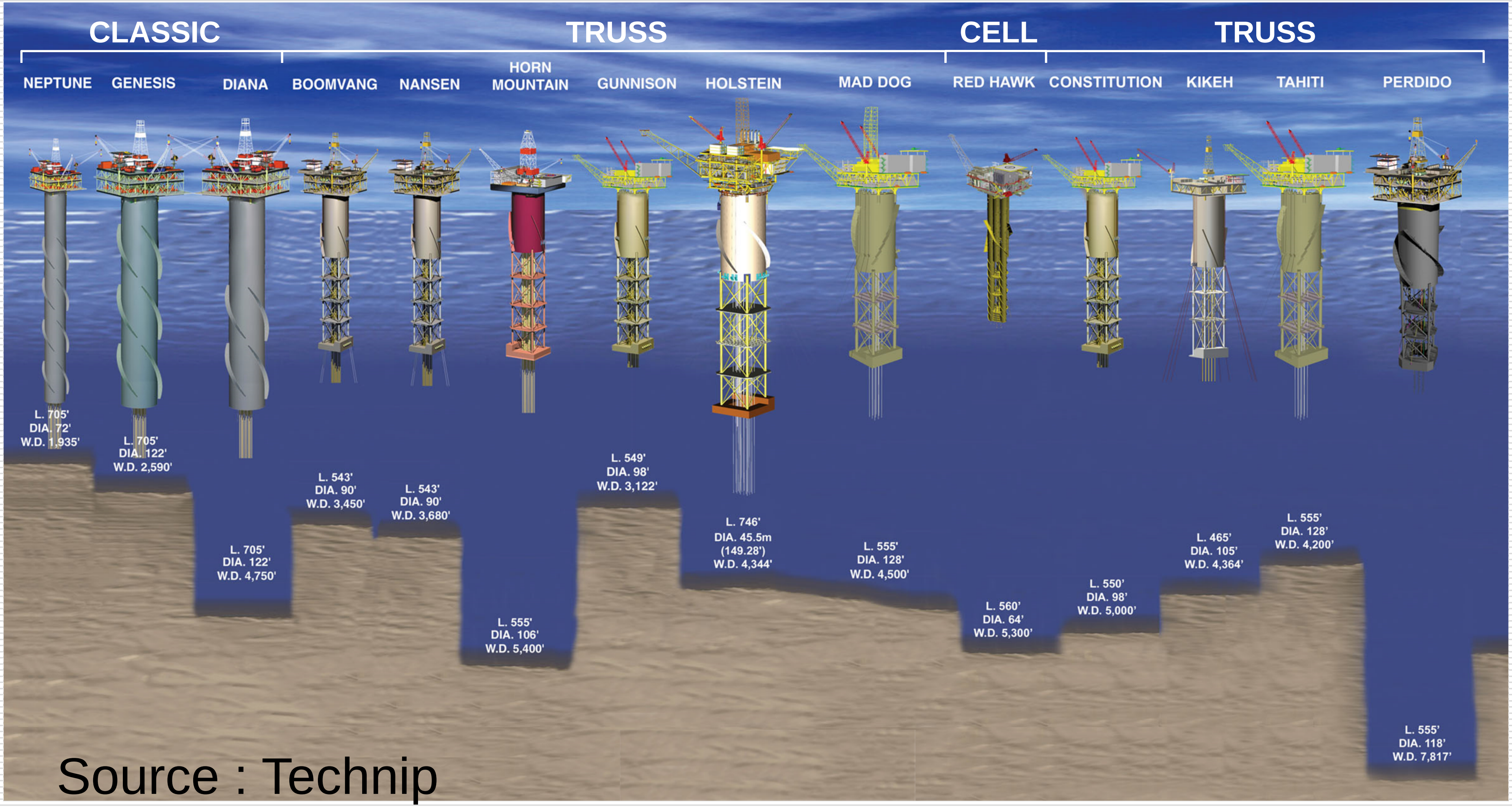
SPAR Hull types



Source : Technip

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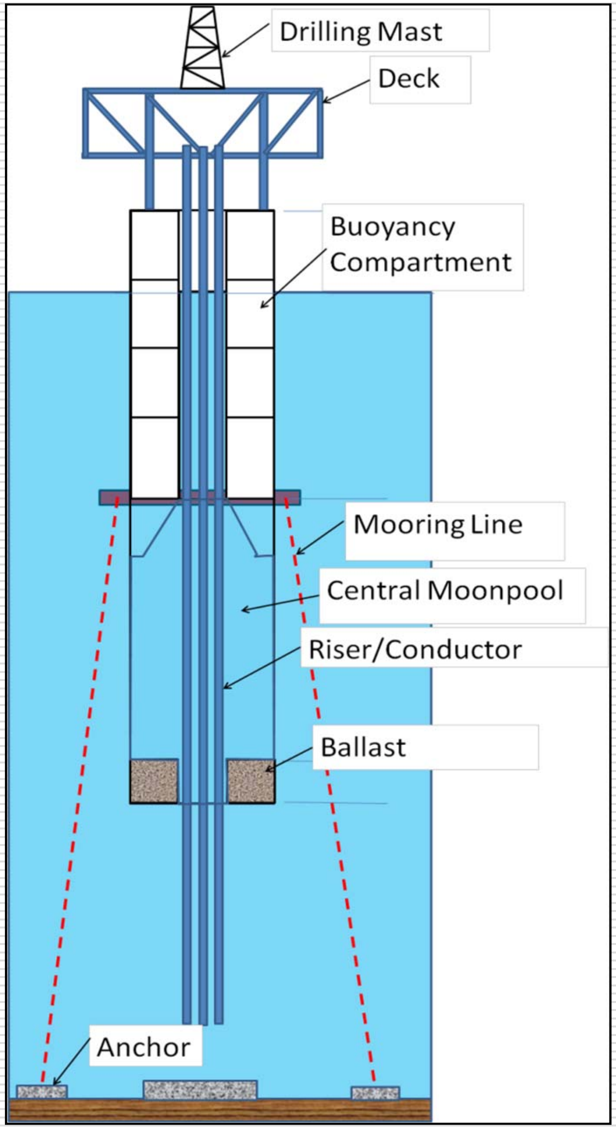
SPAR – Single Point mooring And Reservoir

- A spar is a cylindrical, deep-draft, floating caisson, which has a hollow cylindrical structure. Its major systems are:
  - ✓ Hull
  - ✓ Moorings
  - ✓ Topsides
  - ✓ Risers
- Spar uses traditional anchor-spread mooring system to maintain its position. Approximately 90% of the spar structure remains underwater.
- Historically, spars were used as
  - ✓ Marker buoys
  - ✓ Buoys to gather oceanographic data
  - ✓ Oil storage system.



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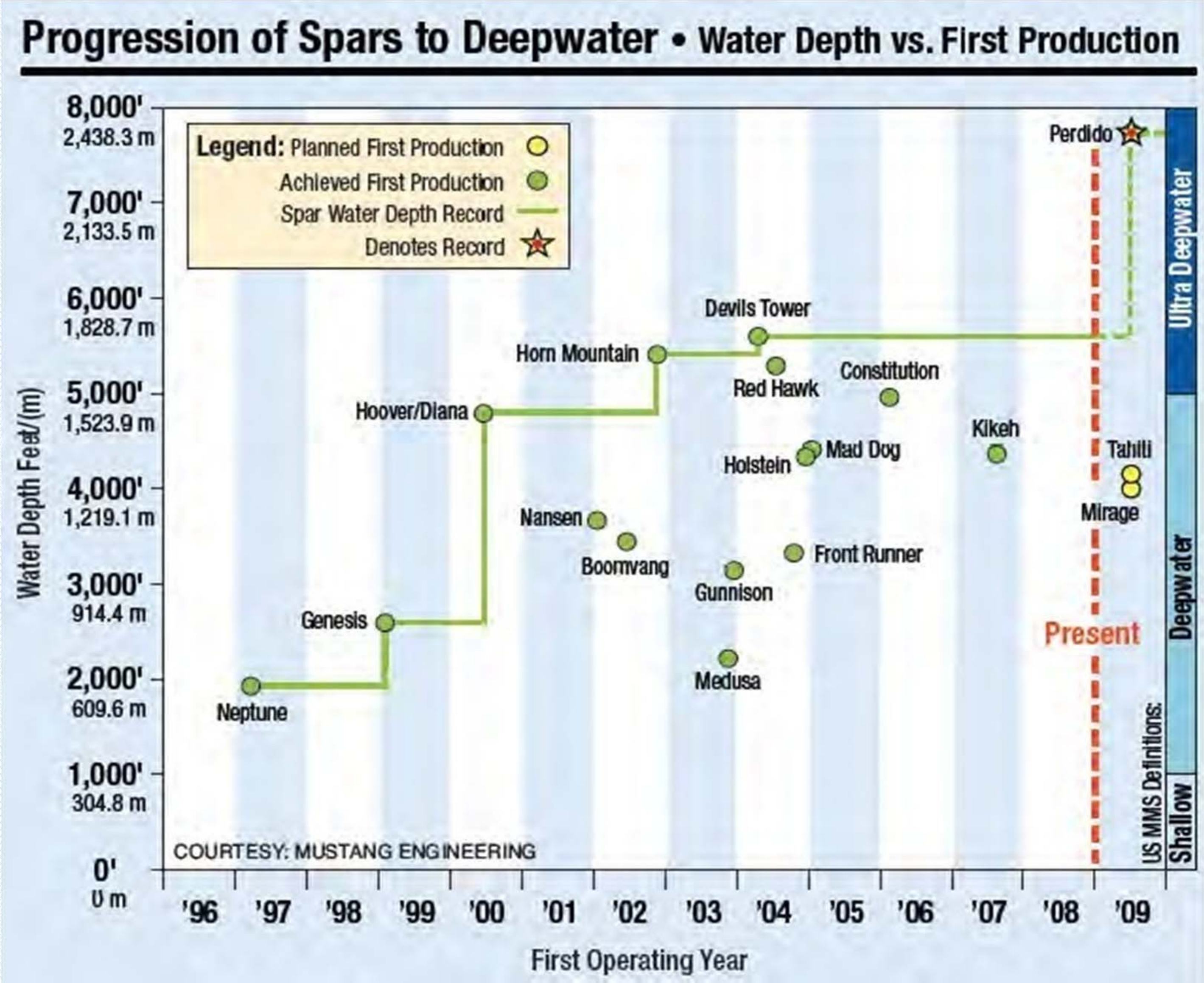
SPAR in deep water

- Spar is one of the floating structure which widely used in deep waters.
- Figure shows the progression of Spar platforms from deep waters to ultra deep waters with in one and half decade.



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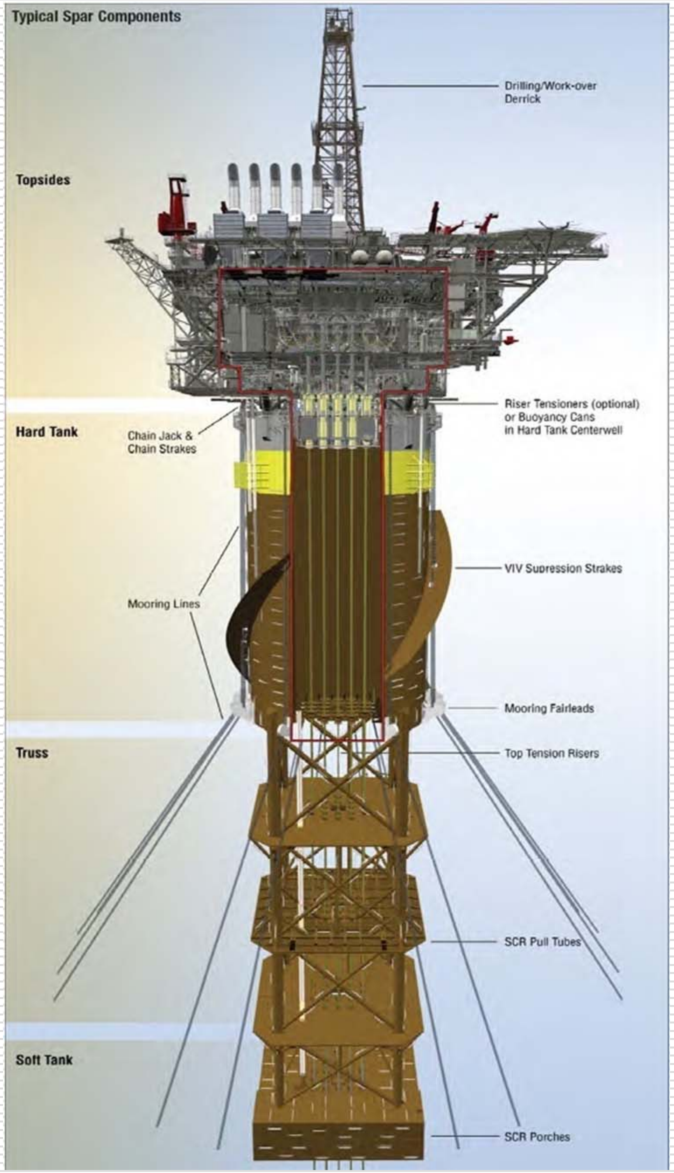
From: Expanding Facilities Knowledge Workshop-Offshore Concept Selection; **Christopher M. Barton**

Design characteristics of SPAR

- SPAR is a deep draft cylindrical hull which floats upright.
- Its payload is supported by buoyancy.
- It is moored to seabed by Taut or Catenary mooring lines.
- Combined "Centre of Gravity" of payload, SPAR and ballast is located below the Centre of Buoyancy.
- It has large volume for storage (Reservoir).
- SPAR is "unconditionally stable".



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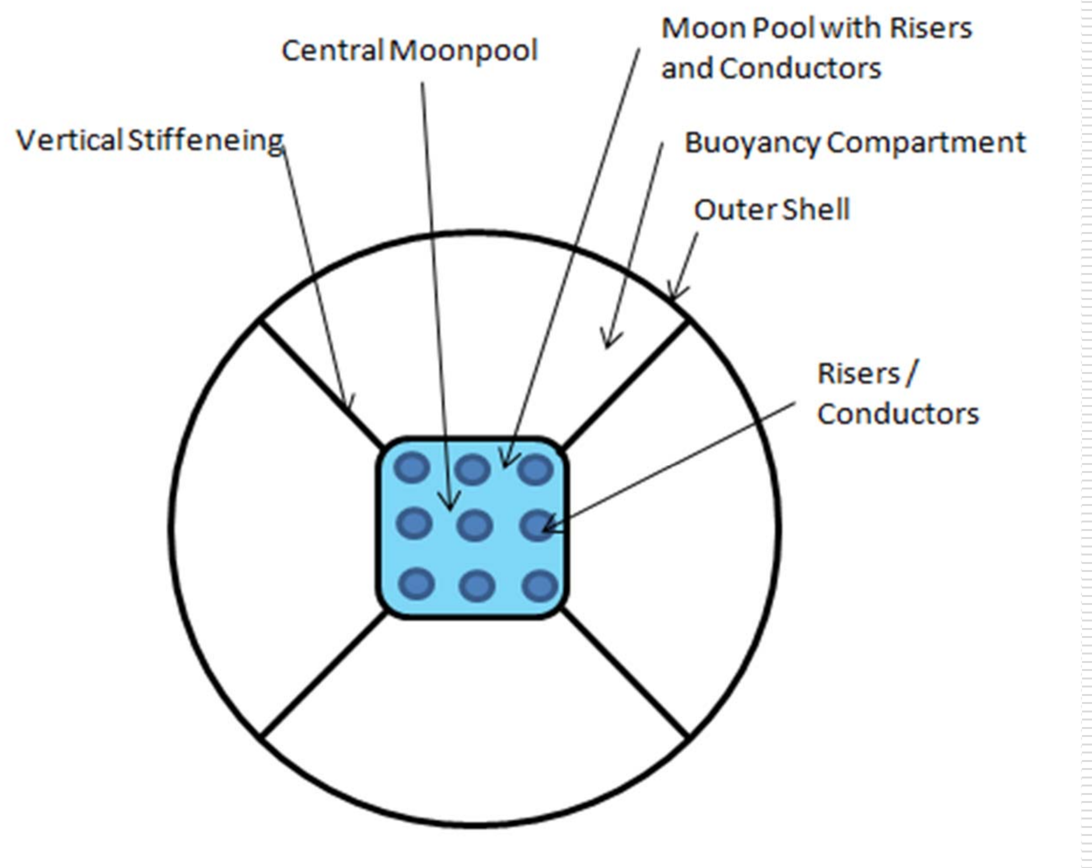
TYPICAL SPAR Hull Section

- Central area is reserved for array of wells and risers called “Moonpool”
- Outer shell is divided in to compartments both in horizontal and vertical
- Compartment design is similar to ship compartments.
- Compartments can be used for oil storage or Ballast



CIRCULAR HULL

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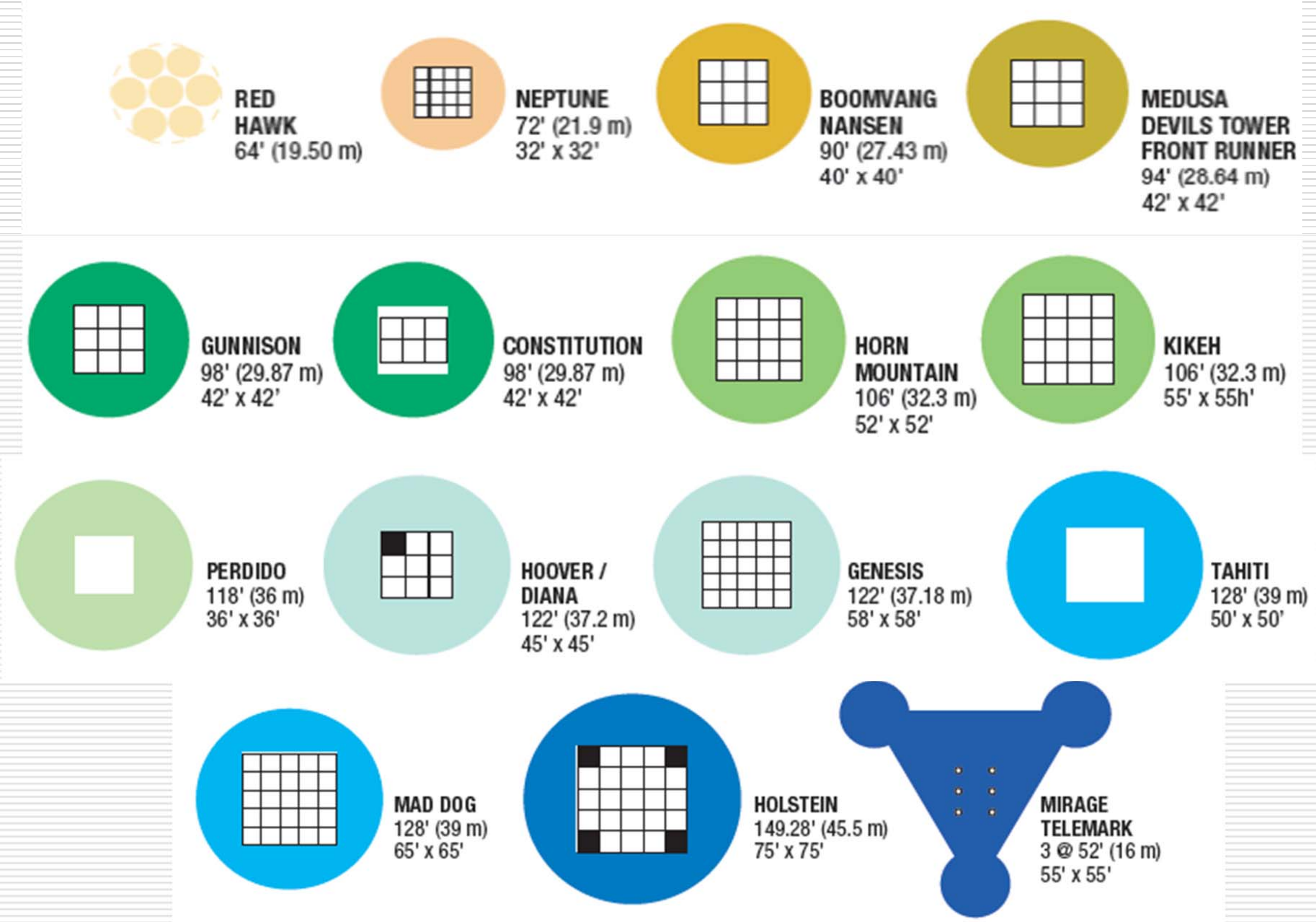
Spar Hull Diameter Comparison



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Spar Flexibility and Scalability

Holstein Truss Spar

- # Dry Trees – TTR's: 20
- # SCR's: 2
- Pay Load: **37,000 mt**

Red Hawk Cell Spar

- # Subes Trees: 2
- # SCR's: 3
- Pay Load: **5,460 mt**

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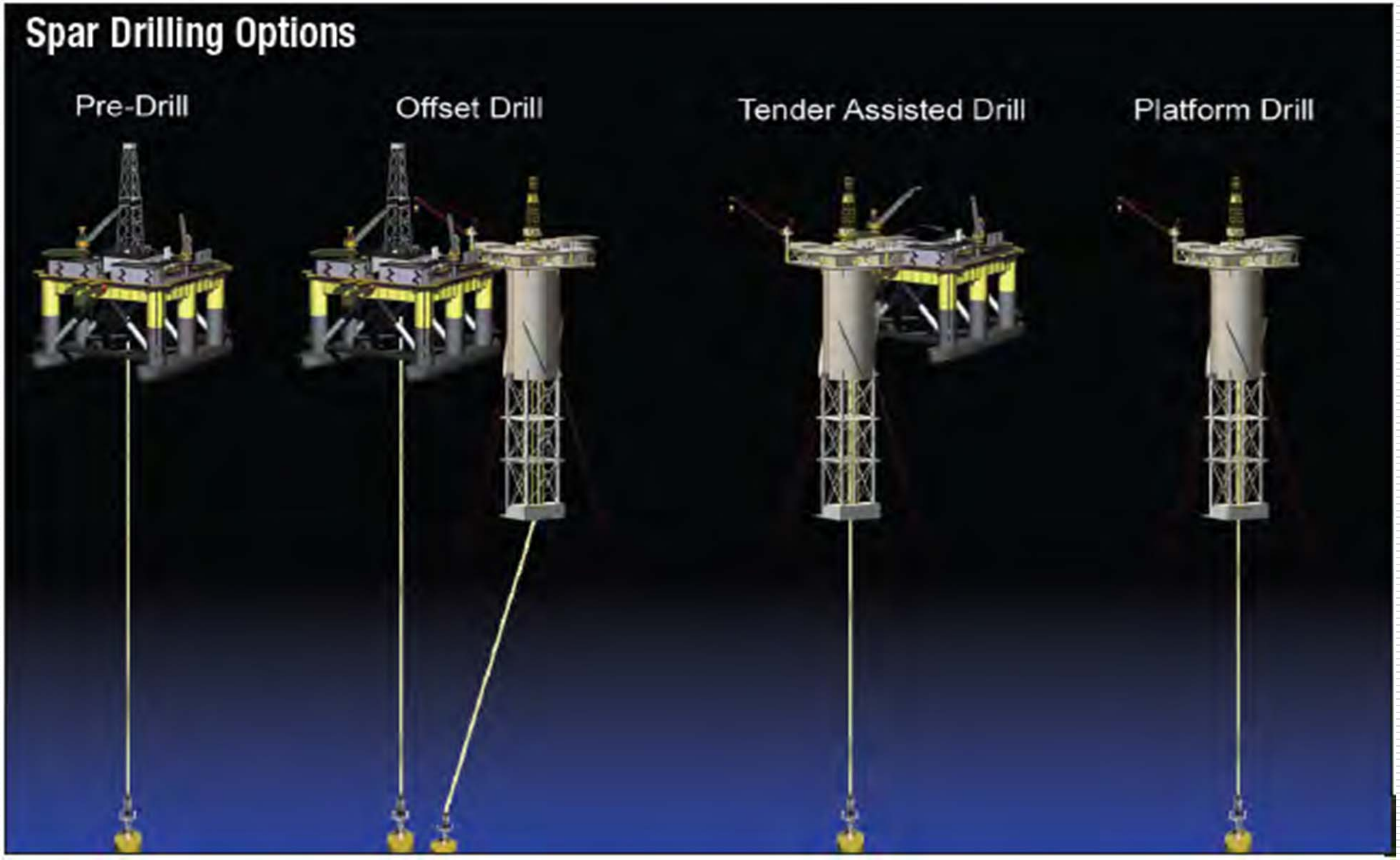
Spar Drilling Concepts



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Hull Design Drivers

- Payload
- Hard tank compartmentation
  - ✓ Ballasting
  - ✓ Variable (sea-water)
  - ✓ Fixed (magnetite)
  - ✓ In-hull storage of chemicals, diesel, etc.
- Fabrication & installation
  - ✓ Yard limitations (skidway spacing, quay depth, cranes)
  - ✓ Heavy lift transport vessel
  - ✓ Offload draft
  - ✓ Wet tow & up-end (keel tank sizing)
  - ✓ Topside lift
- Performance criteria (pitch, surge & heave) →

Heave Response

Heave response is an important parameter for drilling and production risers as it will determine the flexibility required for the design. Typically it shall be restricted to 2 to 4m.

Pitch Response

Pitch response depends on the set-down and typically is less than 4 degrees for operational condition and 10 degree for survival condition.

Surge Response

Surge response depends on the flexibility in the mooring system. Typically a surge value of 3% of water depth is allowed.

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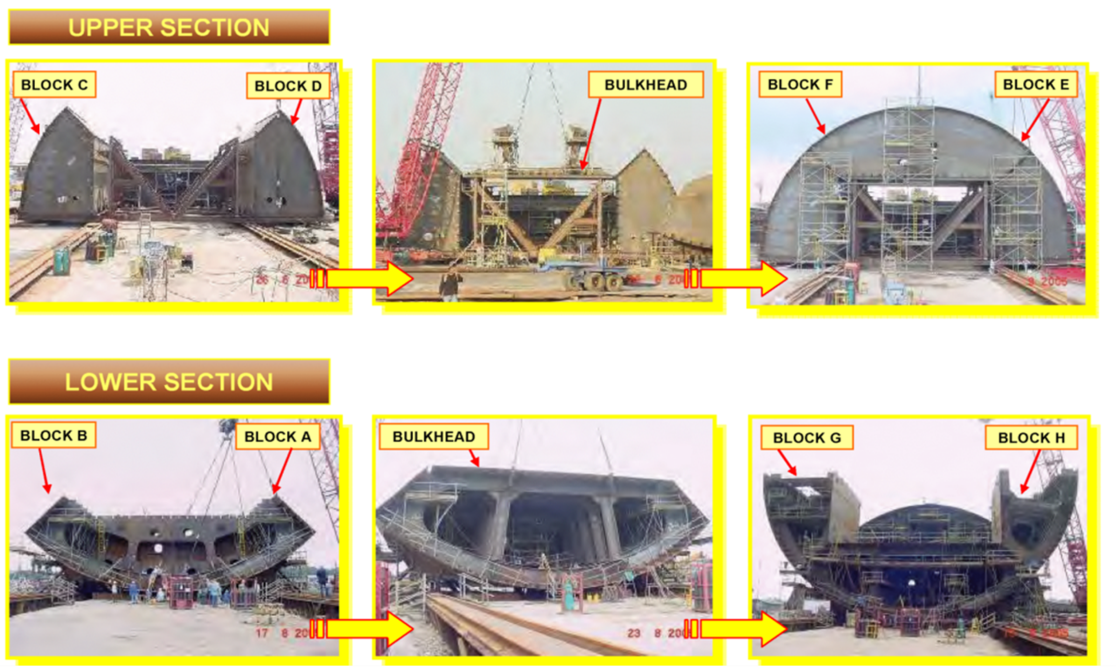
FABRICATION

- Fabrication is a conventional yard based method similar to ship yard construction.
- Sub-assemblies can be made and assembled.



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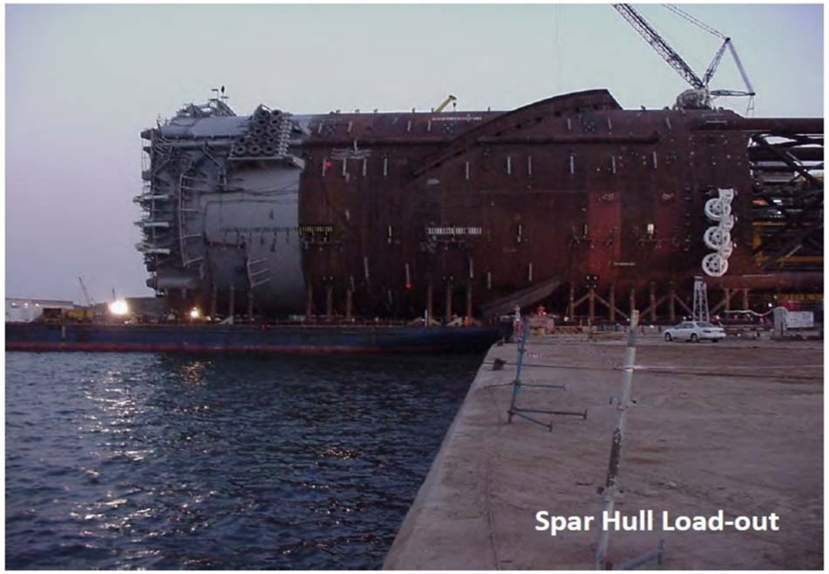
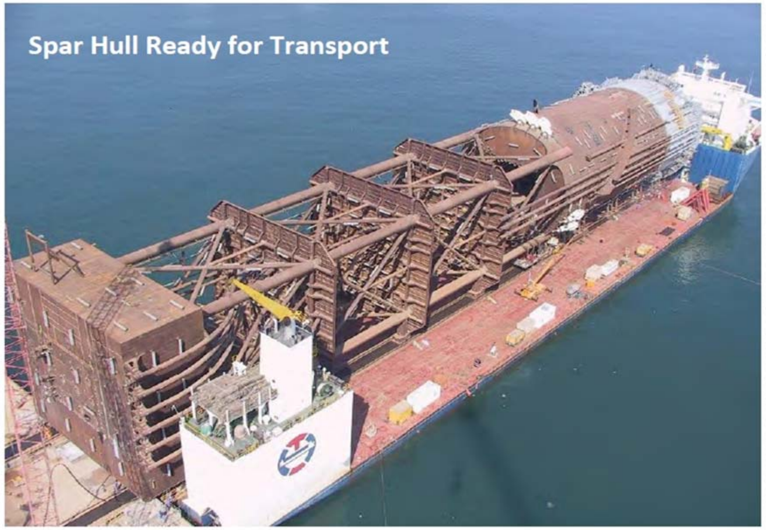
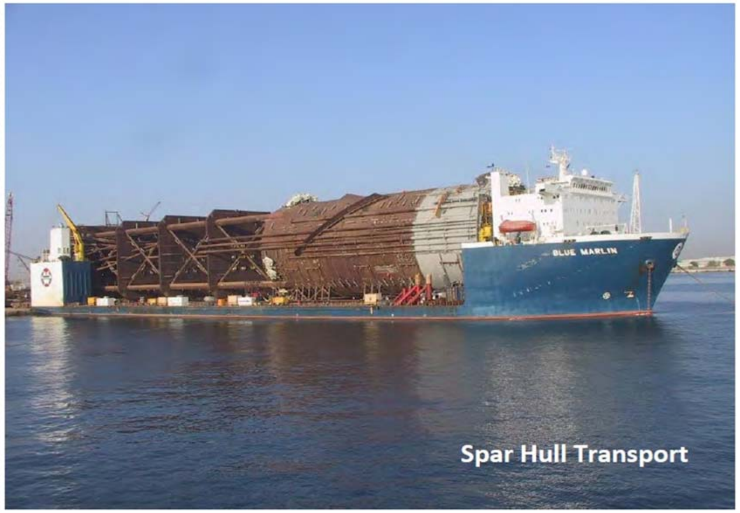
LOADOUT AND TRANSPORT

- Conventional loadout and dry transportation
- Semi-submersible barge used for float-off offshore location







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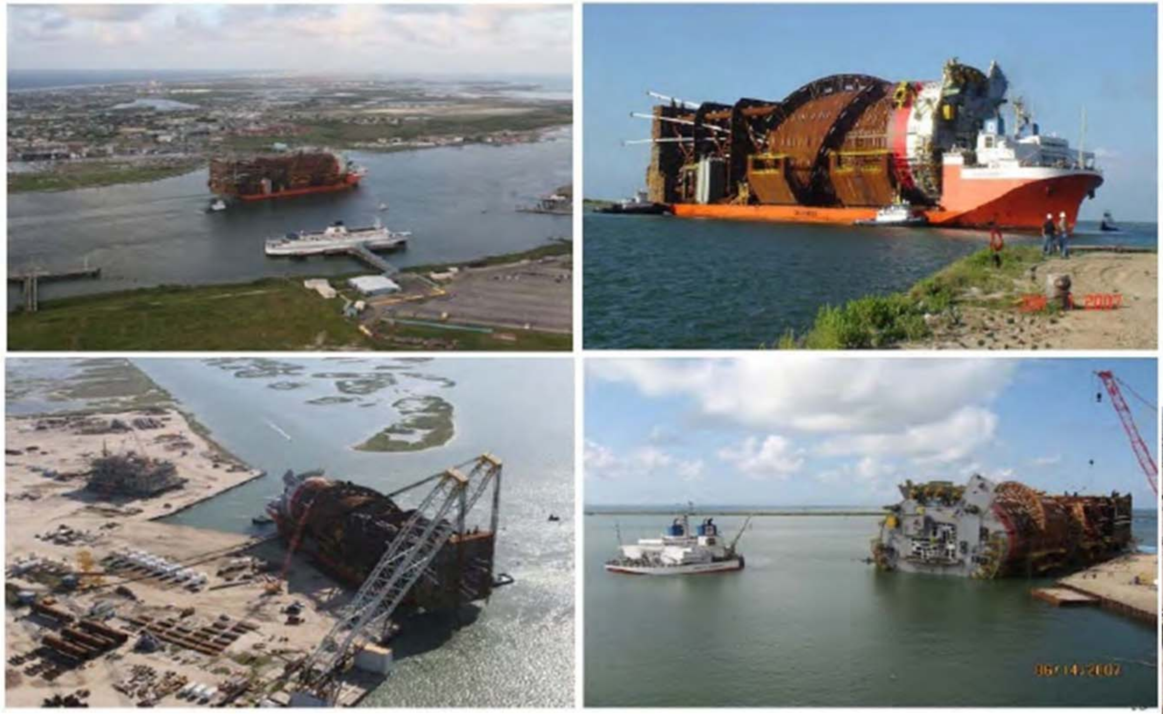
Spar Hull Offload



Spar Hull Wet Tow and Upend

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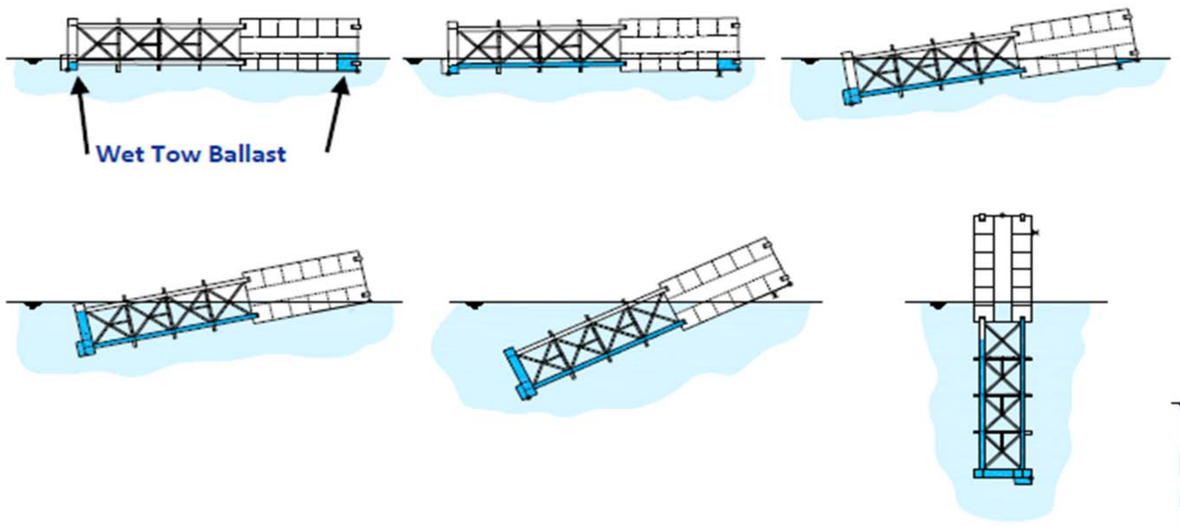
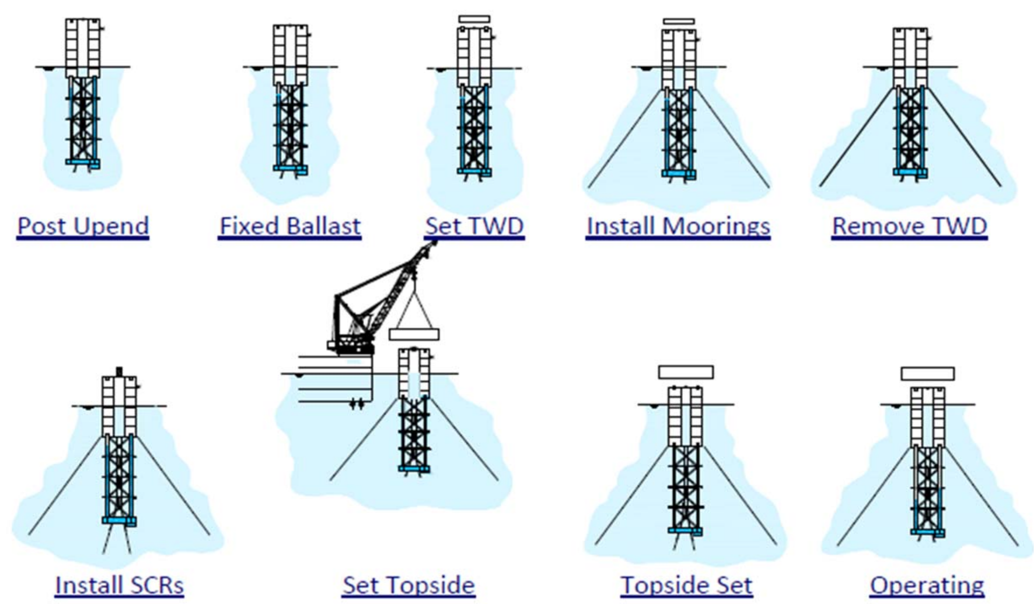
Hull Up-end Sequence



Post Up-end Stages



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Concepts for Deep Water Field Development – Eastern Offshore

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Spars Installed

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RESEARCH AT IIT MADRAS

- The hydrocarbon exploration in to deep water has been thrust a area for some time as the shallow water exploration has come to an end as most of the fields are exhausted.
- The Spar concept has been in use for hydrocarbon exploration for nearly three decades. A focused research on the hydrodynamic response on the following areas has been carried out.
  - Geometric Shapes
  - Additional damping elements
  - Variation of heave plate size
  - Heave Plate geometry and added mass
- Experimental and numerical simulation of the hydrodynamic response of spar hulls have been carried out for following cases
  - Shapes (Circular, Pentagon and Octagonal)
  - Heave plate of various diameters and position
  - Bottom Enlarged Base
  - Cell Spar (6 and 8 cells)
  - Parametric study

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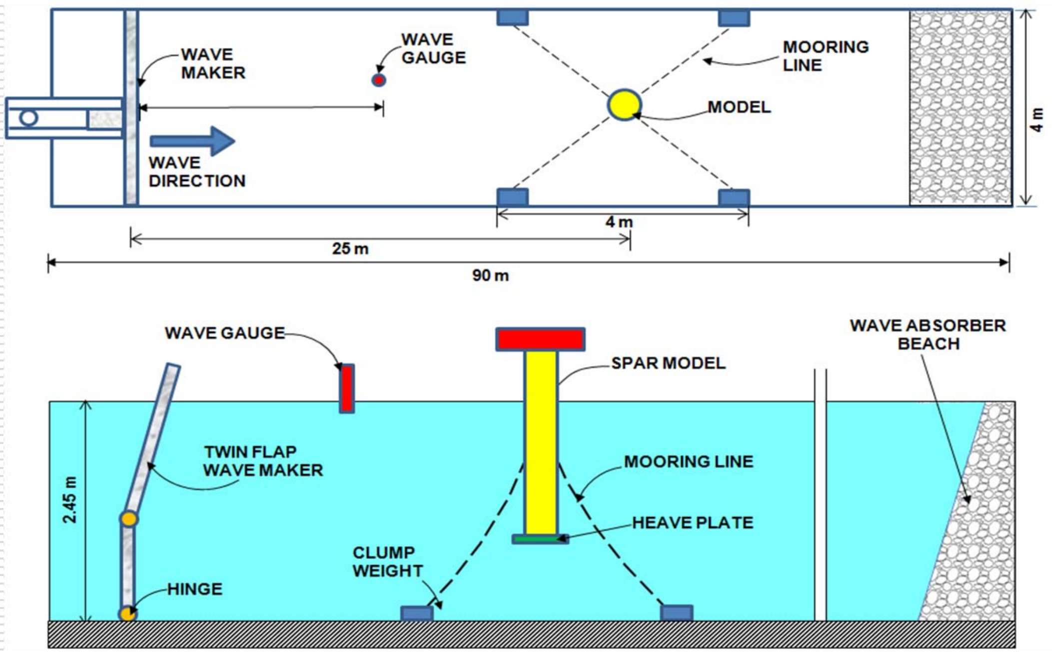
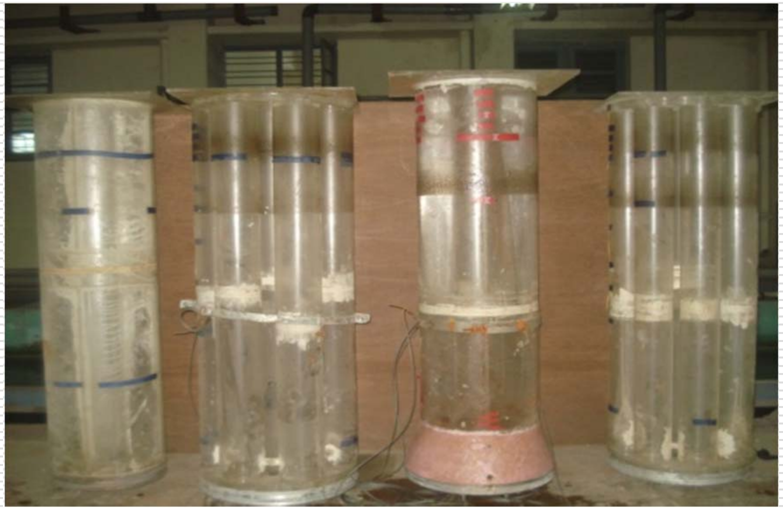
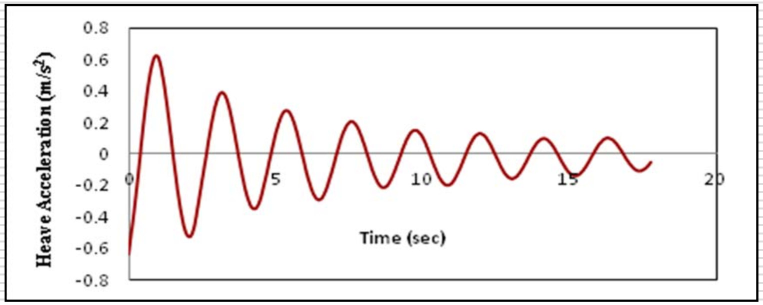
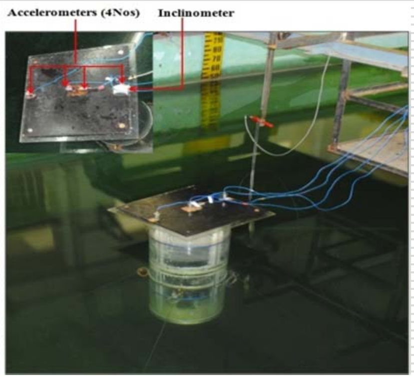
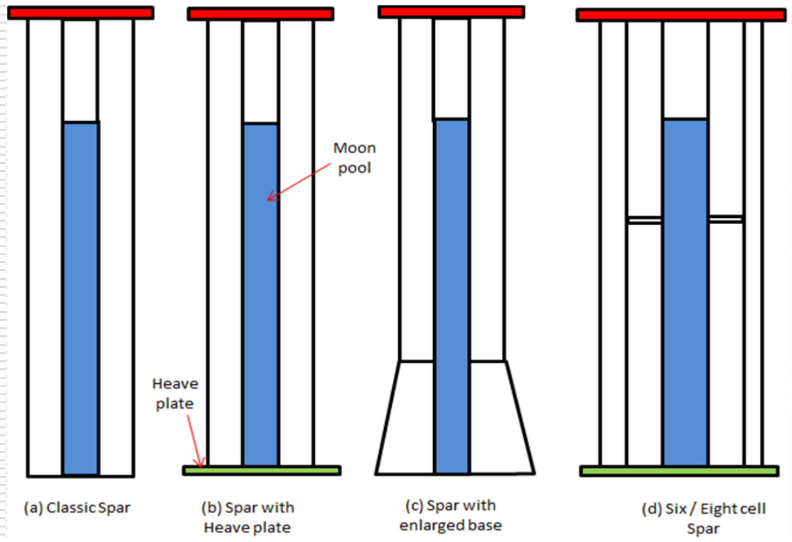
Effect of Spar Hull geometry











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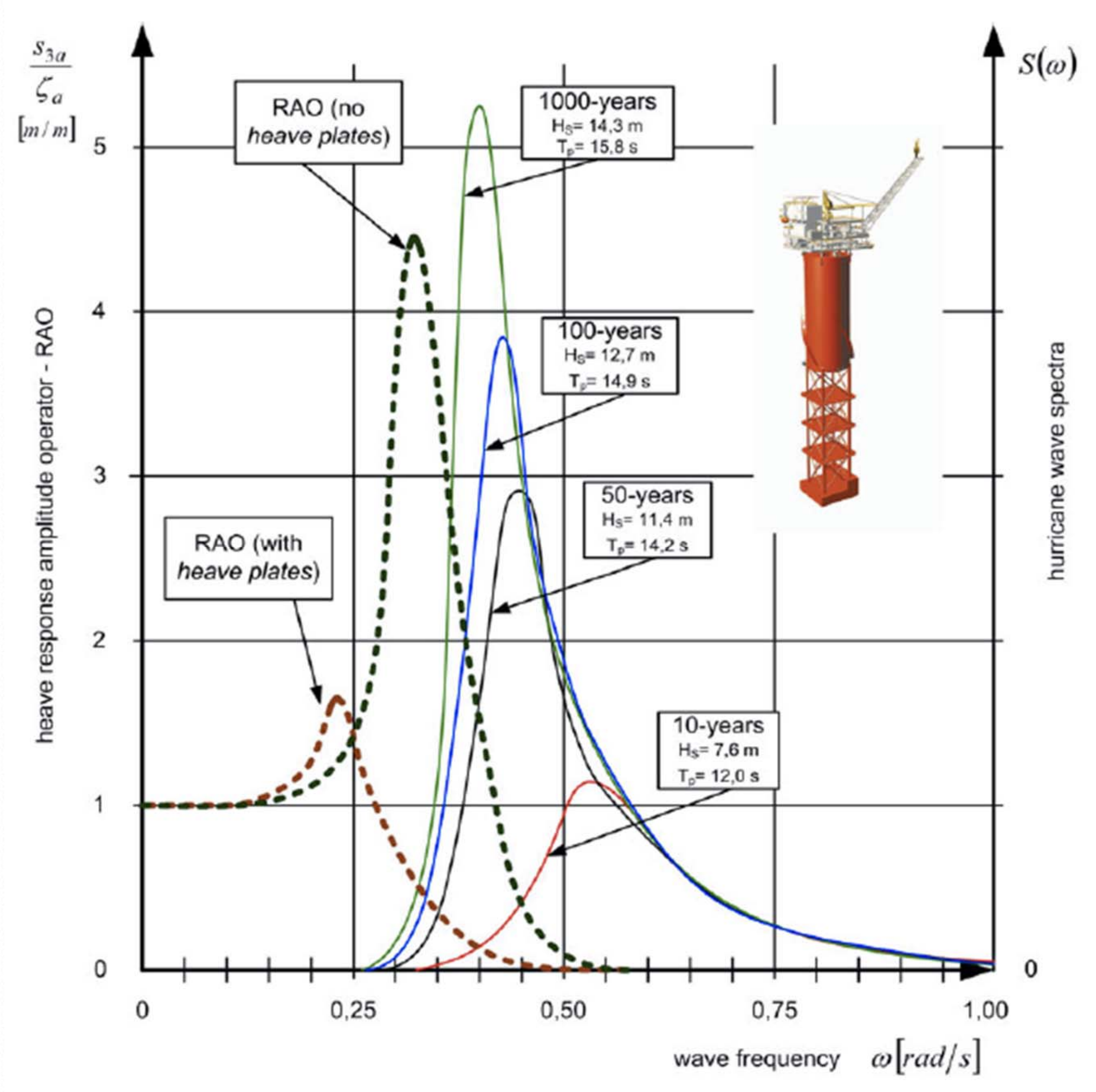
Wave spectra and the RAO of Spar platform

- Addition of heave plates in Spar have reduced the peak heave RAO from 4.5m/m to 1.75m/m (>100%).
- The heave natural frequency has also been shifted away from wave spectra, due to the addition of heave plate.



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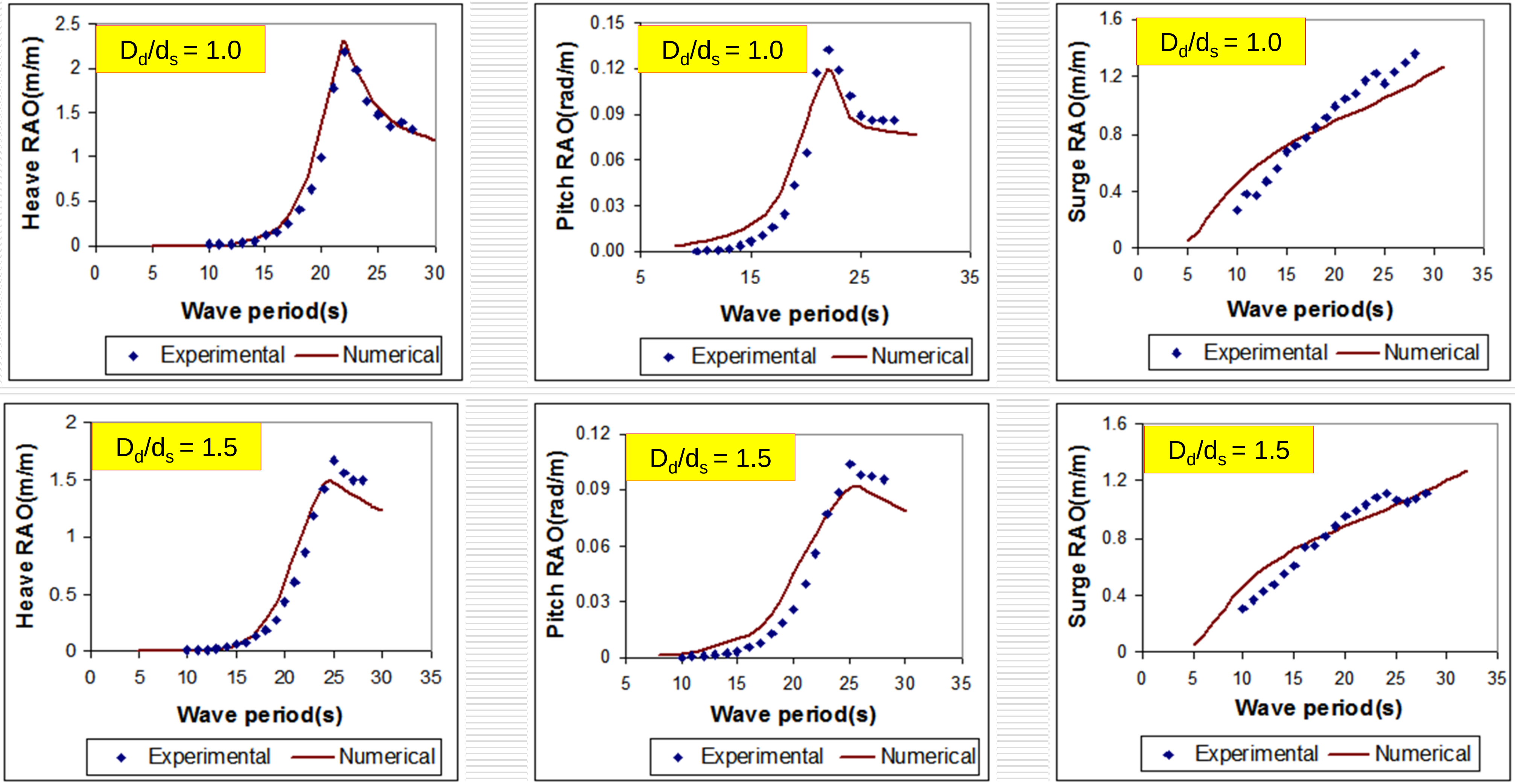
Effect of Heave Damping Plate size at the bottom

Comparison of Heave, Pitch and Surge RAO (Measured and Computed) for D_d/d_s=1.0 and 1.5



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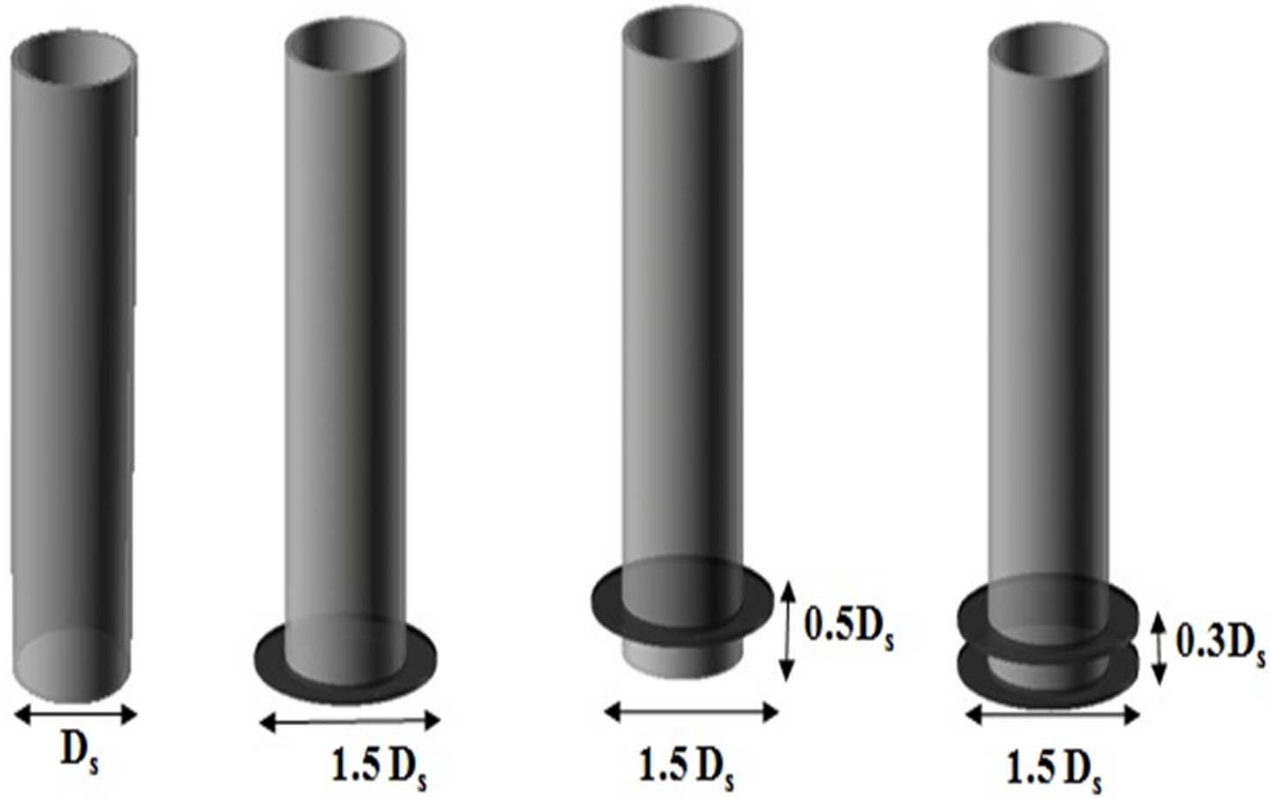
Effect of heave plate geometry

- The effect of heave plate location, and number has been investigated for the selected configurations as shown in the figure.

- Estimation of added mass using proposed geometric shapes is compared with that obtained from free decay tests and CFD simulation.

- The heave added mass plays a major role in the excitation force and the hydrodynamic response.



(a) (b) (c) (d)

$$F_3 = \left[A_w \rho g \frac{H}{2} \frac{\cos shk\,(d - d_f)}{\cosh kd} - \omega^2 A_{33} \frac{H}{2} \frac{\sinh k(d - d_f)}{\sinh kd} \right] \sin \omega t$$

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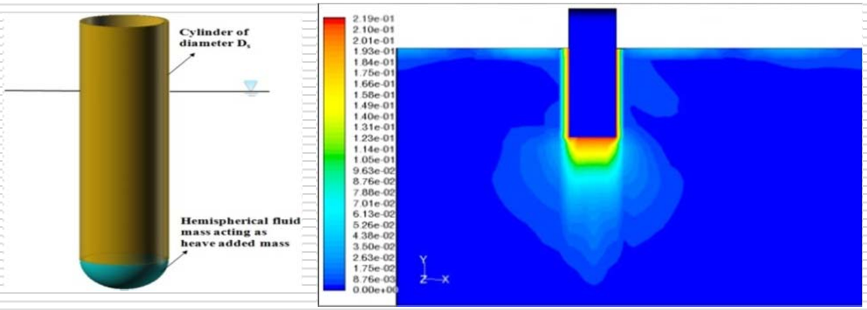
Effect of heave plate geometry – CFD simulation / Parametric calculation

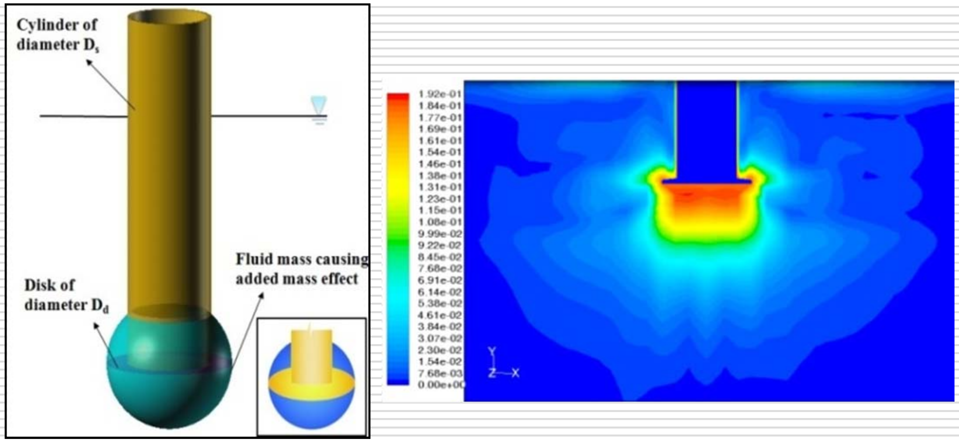
Estimation of added mass by geometric shapes

(a)



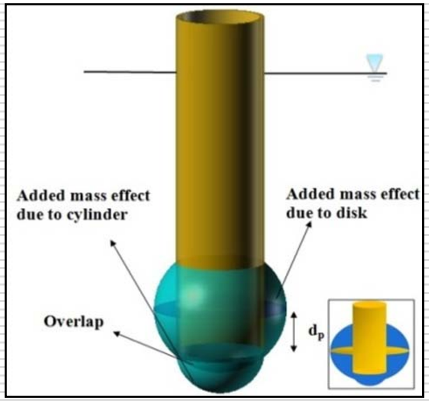
$$m_a = A_{33} = \frac{2}{3}\pi\rho\frac{D^3}{8} = 2.09\rho\frac{D^3}{8}$$

(b)



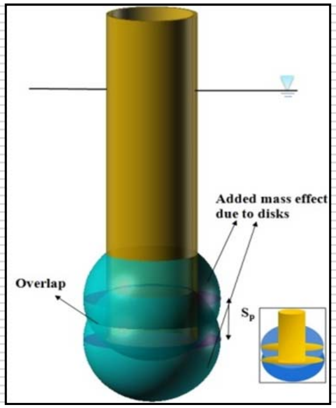
$$A_{33} = \frac{1}{3}\rho D_d^3 - \left[\frac{\rho}{4}D_s^2\sqrt{D_d^2 - D_s^2} + \frac{\rho}{12}\left(D_d\sqrt{D_d^2 - D_s^2}\right)^2\left(2D_d\sqrt{D_d^2 - D_s^2}\right)\right]$$

(c)



$$A_{33} = \frac{1}{3}\rho D_d^3 \left[\begin{array}{l}\frac{\rho}{4}D_s^2\left(d_p + \sqrt{D_d^2 - D_s^2}\right) \\ +\frac{\rho}{12}\left(D_d - \sqrt{D_d^2 - D_s^2}\right)^2 \\ \left(2D_d - \sqrt{D_s^2 - D_d^2}\right)\end{array}\right] + \frac{\rho}{12}\left(D_s - D_d + 2d_p\right)^2\left(2D_s - D_d + d_p\right)$$

(d)



$$A_{33} = \frac{1}{3}\rho D_d^3 \left[\begin{array}{l}\frac{\rho}{4}D_s^2\left(S_p + \sqrt{D_d^2 - D_s^2}\right) \\ +\frac{\rho}{12}\left(D_d - \sqrt{D_d^2 - D_s^2}\right)^2 \\ \left(2D_d - \sqrt{D_s^2 - D_d^2}\right)\end{array}\right] + \frac{\rho}{3}\left(S_p\right)^2\left(6D_d - 2S_p\right)$$

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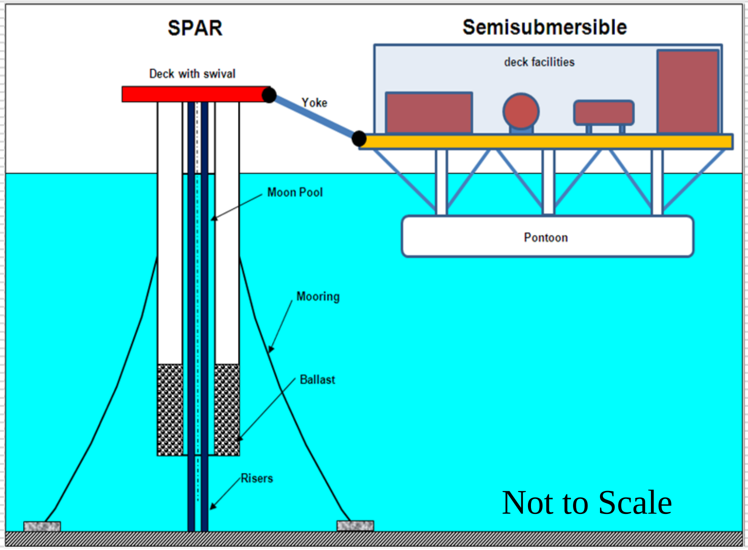
Hydrodynamic response of Spar inter-linked with Semi-submersible

- Floating structure is kept in station by spread mooring or by single point mooring (SPM).
- The components of a SPM are buoy or tower, hawser or rigid yoke and a floating unit.
- FPSO with turret is moored to seabed by mooring lines.
- Floating unit can be disconnected from buoy / tower.
- Risers/cold water pipes are mounted on spar.
- Deck facilities are mounted on semi-submersible.
- Spar designed for 100 year survival wave environment
- Semi-submersible designed for one year operating wave environment.



Schematic view of Spar – Semi-submersible inter-linked by a rigid yoke

- During extreme weather conditions at offshore, semi-submersible is disconnected from spar and towed to the calm Sea

FPSO and Jacket FPSO and Buoy FPSO and MoorSpar

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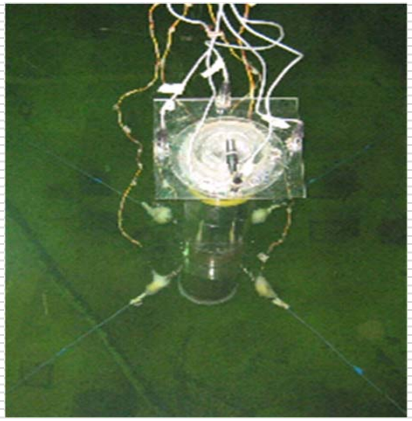
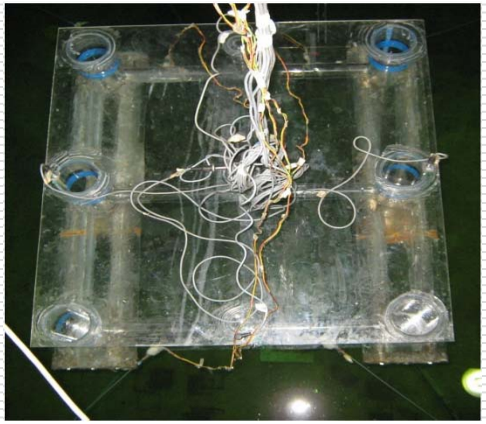
Hydrodynamic response of Spar inter-linked with Semi-submersible

Tests on scale models in wave basin

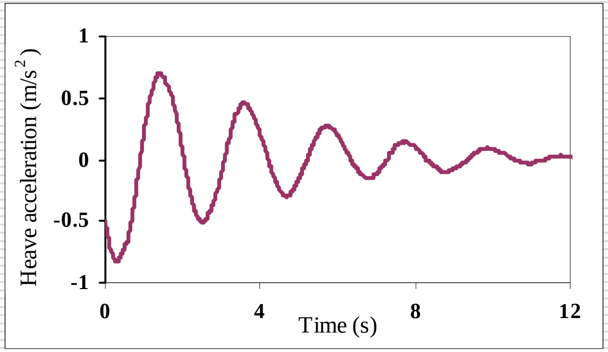
Free vibration decay record



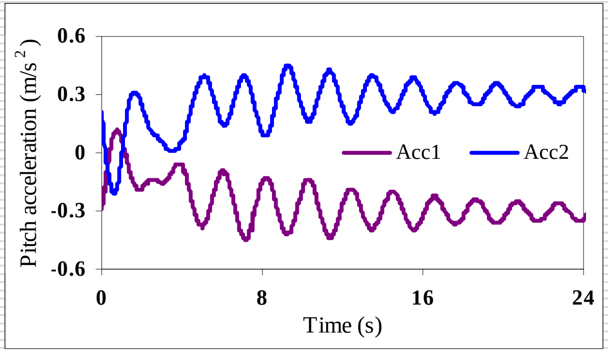
Spar alone



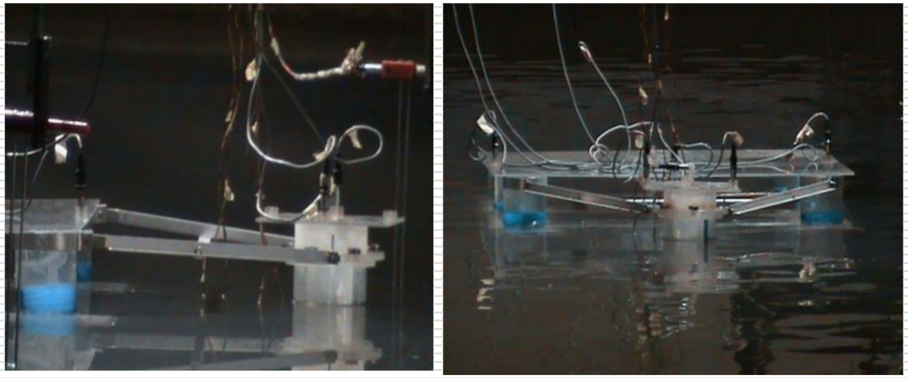
Semi-submersible alone



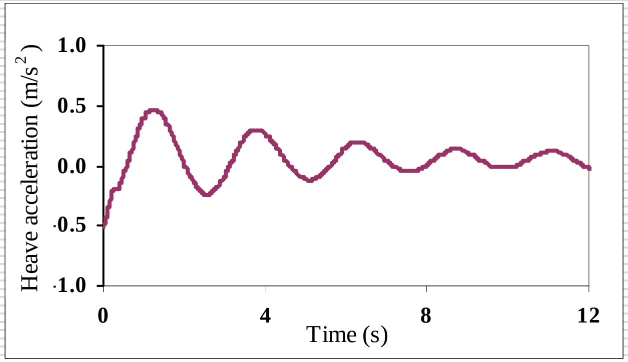
Spar - Heave



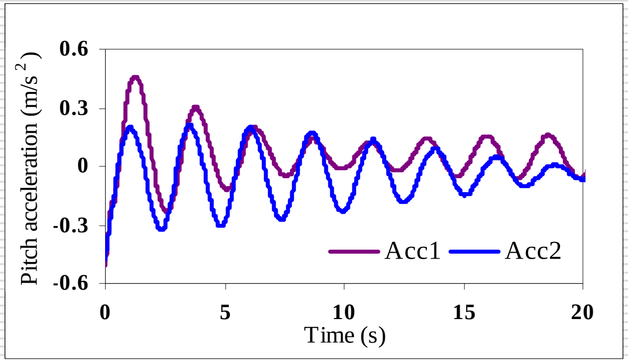
Spar - Pitch



Linked system



Semi-sub - Heave



Semi-sub - Pitch

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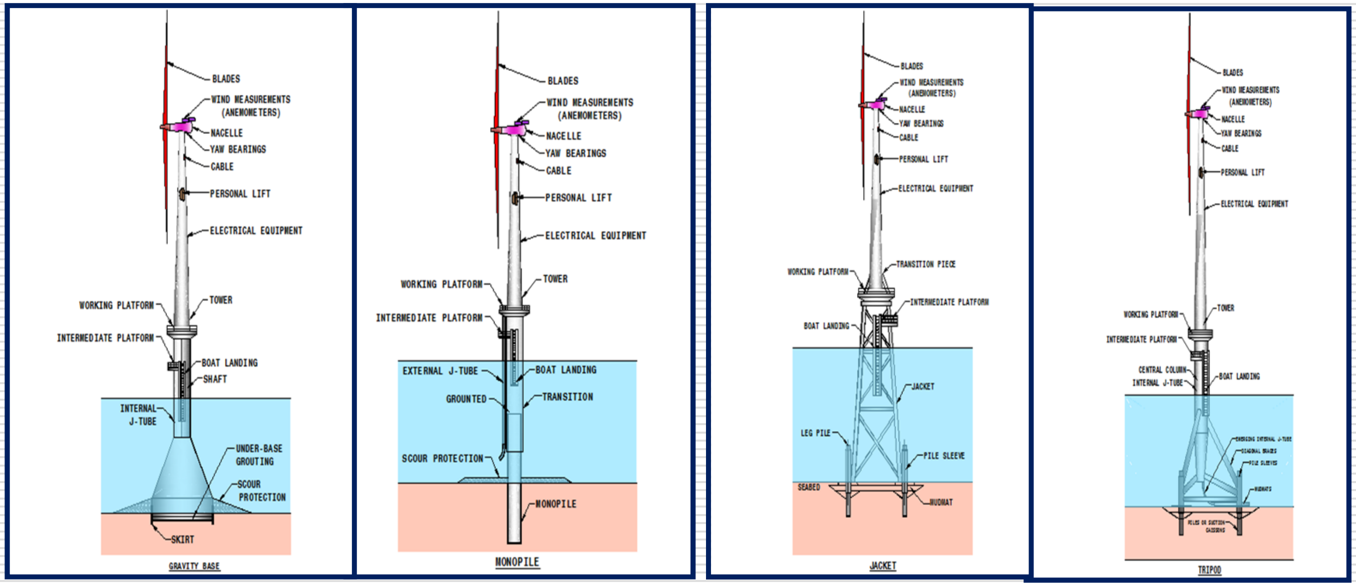
Fixed and Floating Wind Turbine Support Concepts



Shallow water depth

Transitional water depth

Deep Water

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Some International Journal Publications

1) **S.Nallayarasu** and Kirti Bairathi, Hydrodynamic response of spar hulls with heave damping plate using simplified approach, **Ships and Offshore Structures**, Available online from 11th Oct 2013
2) **Nallayarasu S.**, Bhattacharya S. K. and Nimmy Thankom Philip, Damping Characteristics of heave plates attached to spar hull, Proc. of Offshore Mechanics and Arctic Engineering Conf., **OMAE2012**.
3) **Nallayarasu S**, and Sudhakar S, 'Influence of Heave Plate on Hydrodynamic Response of Spar', Proc. of Offshore Mechanics and Arctic Engineering Conf., **OMAE2011**
4) **Nallayarasu S**, R. Sreeraj and M Manusha, Effect of Hull Geometry on the Hydrodynamic Response of Spar in Regular Waves, Special Issue on Coupled Dynamic Analysis of Floating Structures with Concept Technologies : Current Status and Emerging Future Trends, **Ships and Offshore Structures**, Invited article, Available in online, 19th July 2012.
5) **Nallayarasu S**, Sivaprasad P., Weather waning floating structures, **International seminar on "Challenges in deep water structures**, IIT Madras, Dec 2008.
6) **Nallayarasu S**, Sivaprasad P., Coupled Dynamics of Spar and semisubmersible connected By a Rigid Yoke, **International Conference in Ocean Engineering**, IIT Madras 2009.
7) **S. Nallayarasu** and P. Sivaprasad, Hydrodynamic response of spar and semi-submersible inter-linked by rigid yoke under regular waves – Part I, **Ship and Offshore Structures**, Available online from 27th June 2011, 1–13.
8) **S. Nallayarasu** and P. Sivaprasad, Hydrodynamic response of spar and semi-submersible inter-linked by rigid yoke under random waves – Part II, **Ship and Offshore Structures**, Available online from 27th June 2011, 1–9.
9) Nimmy Thankom Philip, **S.Nallayarasu** & S.K.Bhattacharyya, Experimental investigation and **CFD simulation** of heave damping effects due to circular plates attached to spar hull, Ships and Offshore Structures, Available online from 2nd Oct 2013.
10) **Nallayarasu S**, Bhattacharyya S. K and Nimmy Thankom Philip, **CFD Simulation** of Flow around Damping Elements for Floating Bodies in Waves, **ICMCFD**, IIT Madras, 2011.
11) Gopu R Sekhar and **S. Nallayarasu**, Experimental Investigation of Wave Slam and Slap coefficients for array of non-circular section of offshore platforms, **Ships and Offshore Structures**, Available online from 21st March 2012.
12) **Nallayarasu S**, and Gopu R. Sekhar and Wave slam/slap loads on structural members in the air gap, Proc. of **Offshore Mechanics and Arctic Engineering (OMAE)** Conf., 2011.

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Thank you

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