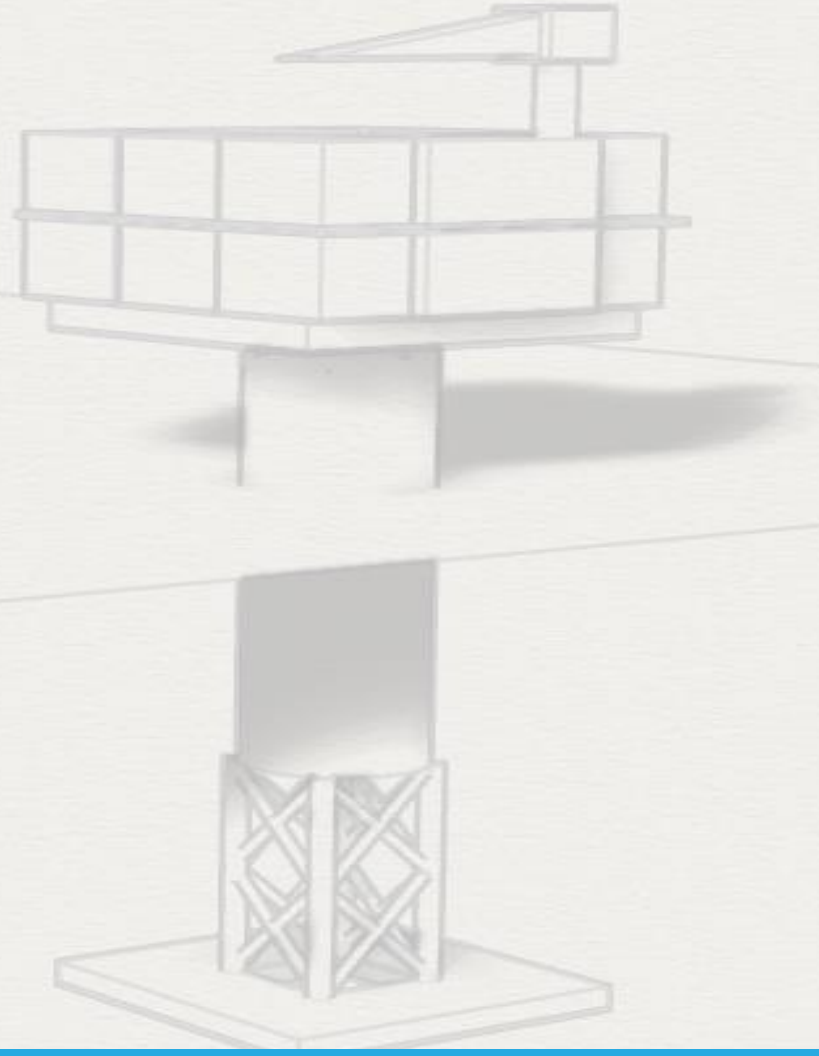
Development of Self-Installing Deepwater Spar



Ashit Jadav
February 2017

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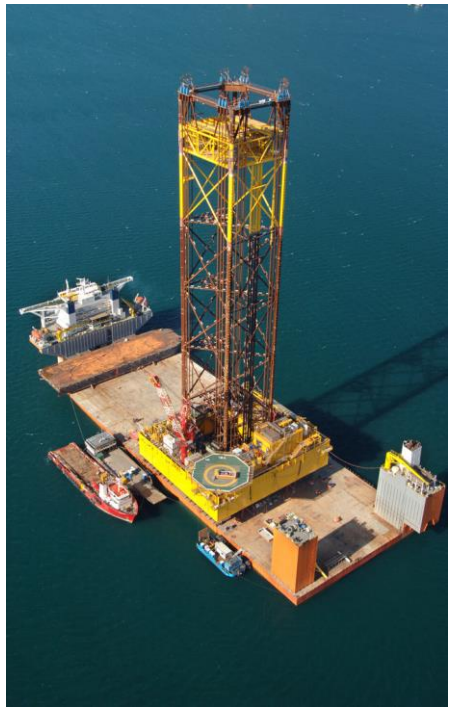
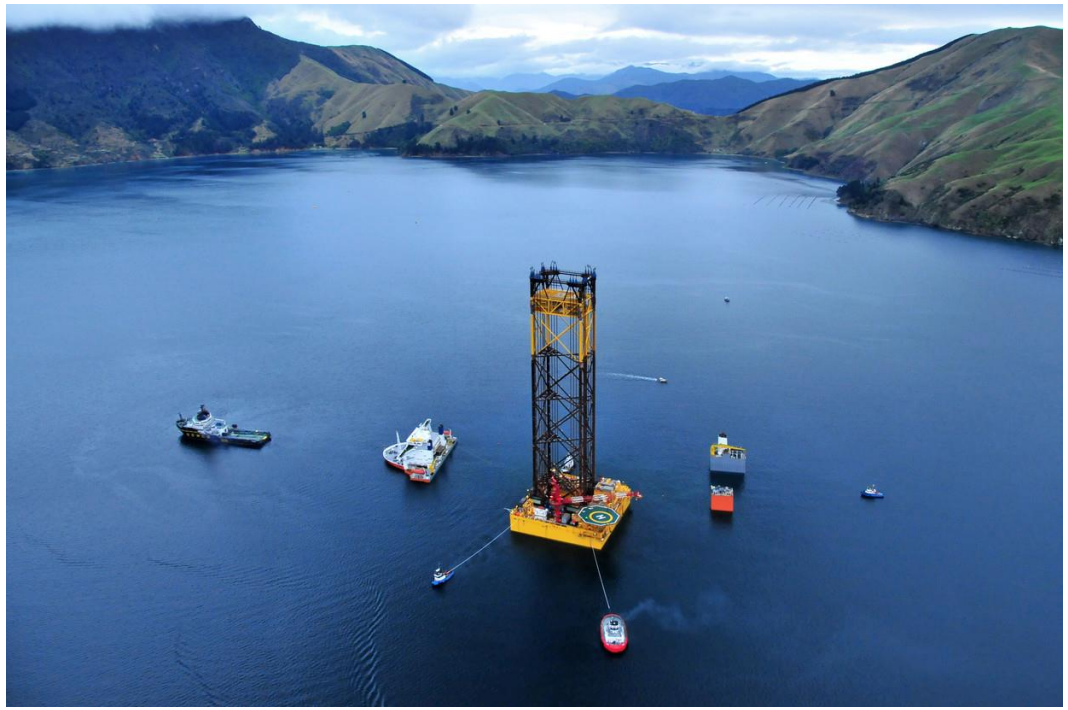
Arup’s ACE platforms

- Arup has successfully designed and installed the award winning ACE (Arup Concept Elevator) range of fixed platforms.





Policy → Concept / Feasibility → Define (Pre-FEED – FEED) → Detailed design → Execute → Operate → Decommission

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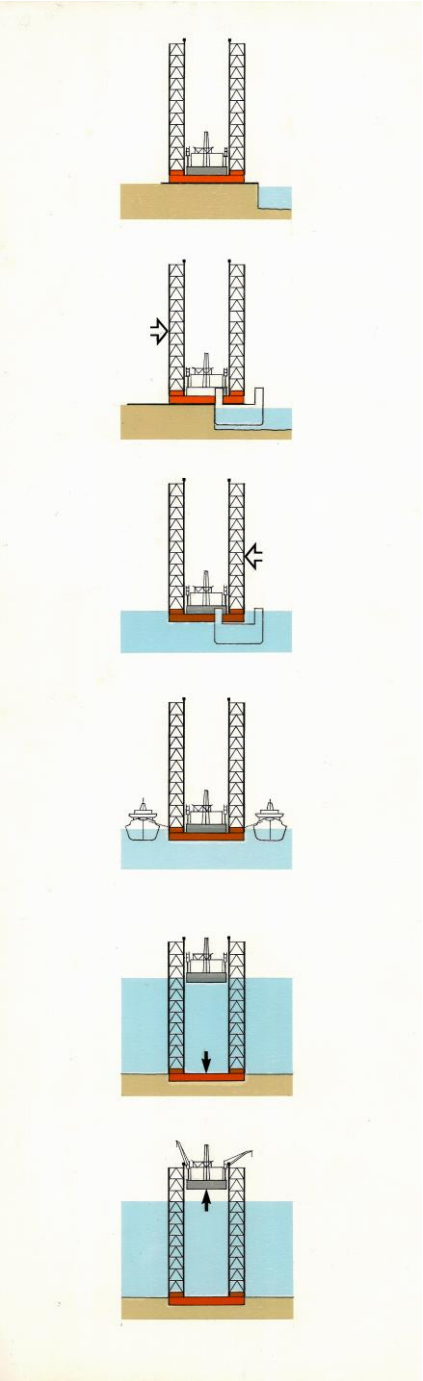
Arup's ACE platforms

- Self-installing fixed platforms
- Re-locatable
- Less intensive offshore campaign
- Strand Jacks used for lifting and lowering
- Comprehensive offshore solution
- Drilling, production, wellhead facilities, offshore wind



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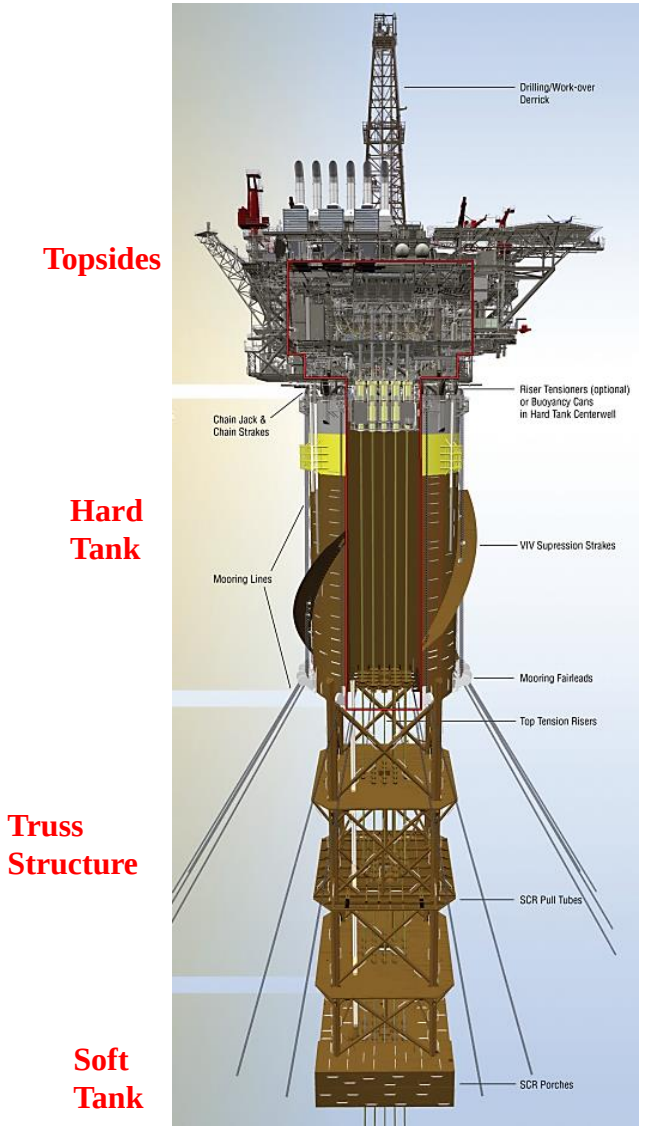
Conventional Spar platforms

- Classic type
- Truss type
- Cell type

The main components of a Truss Spar platform are:

- Topsides
- Hard Tank
- Truss structure
- Soft Tank



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Arup's Deepwater solution

The best of both worlds!

- **ACE platform**

✓ *Enhanced Project Economics due to various reasons*
✓ *Self-installing and re-locatable*
✓ *Minimal requirement of a specialist heavy lift vessel*
✓ *Lifting and lowering system proven in harsh installation conditions*
✓ *Vertical stacking construction for ease of fabrication*

- **Spar platform**

✓ *Supports dry and wet trees*
✓ *Low heave motions*
✓ *Suitable for deep to ultra-deep water depths*
✓ *Provide product storage*

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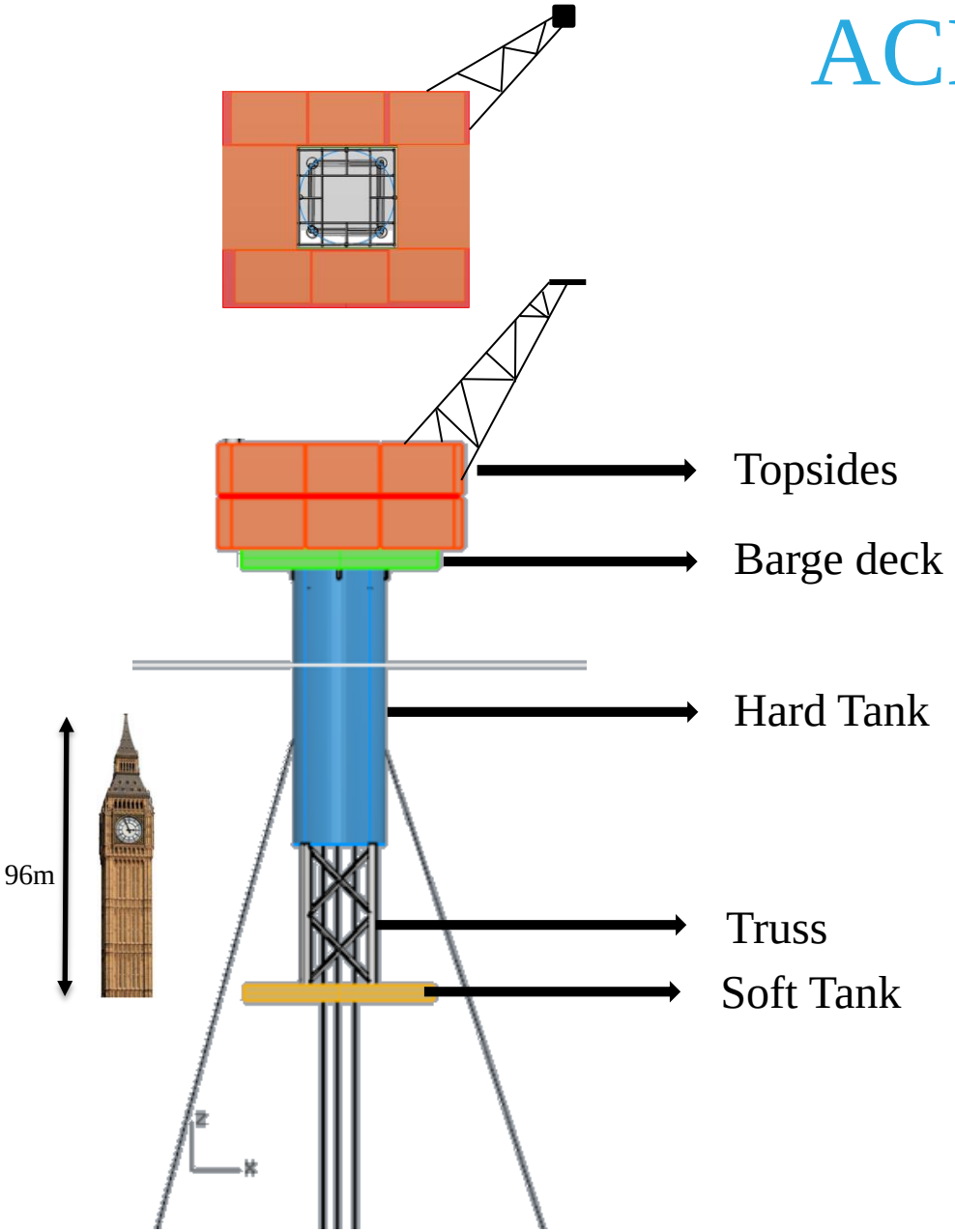
ACE Spar breakdown



Barge deck

- *Primary support for the Topsides*
- *Buoyancy during the wet-tow*

Hard Tank

- *Providing buoyancy or tanks for ballast during Installation & In-place condition*
- *Store product in the Operational phase*

Soft Tank

- *Forms the heave plate*
- *To be used for water ballast + solid ballast if required to maintain a positive GM during Transportation, Installation and In-place condition*

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Installation Sequence

The **Self-Installing** sequence for ACE Spar platform will utilize Strand Jacks and can be divided into three main stages:

- ***Float-out***
- ***Lowering***
- ***Deck raising***

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Float-out

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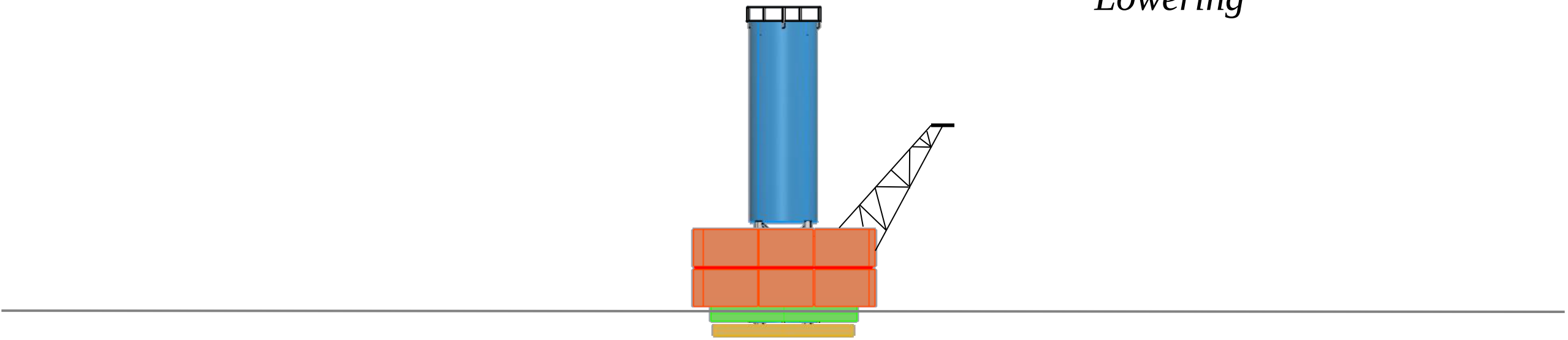
Lowering



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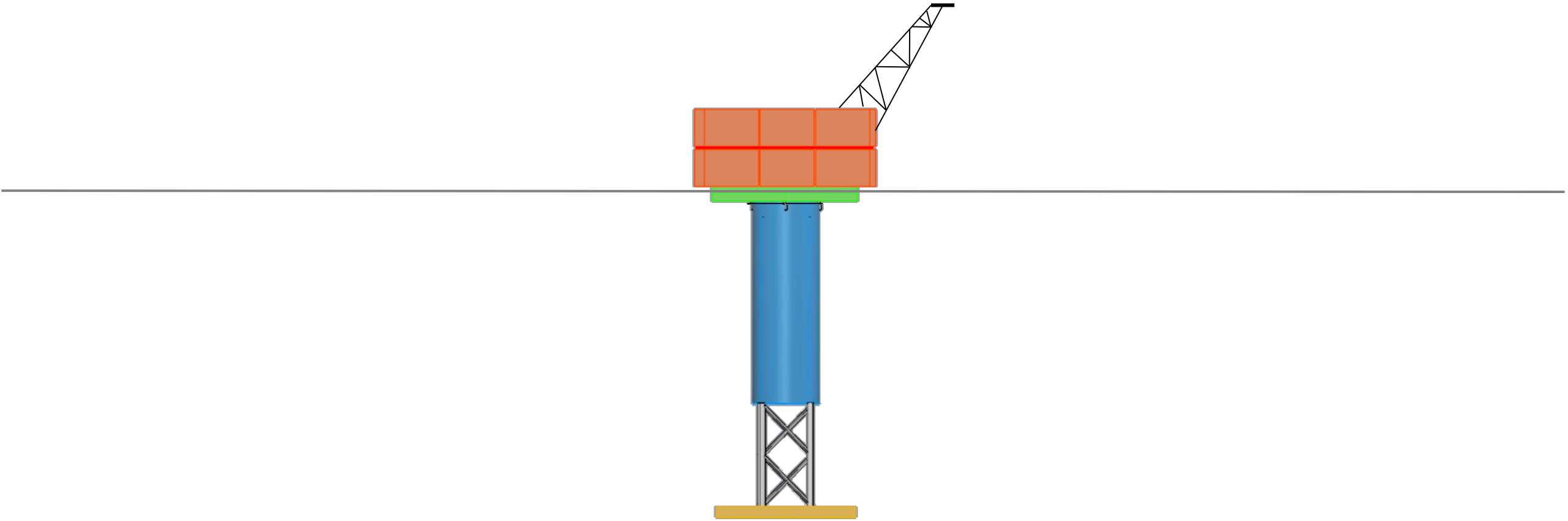
Deck-raising



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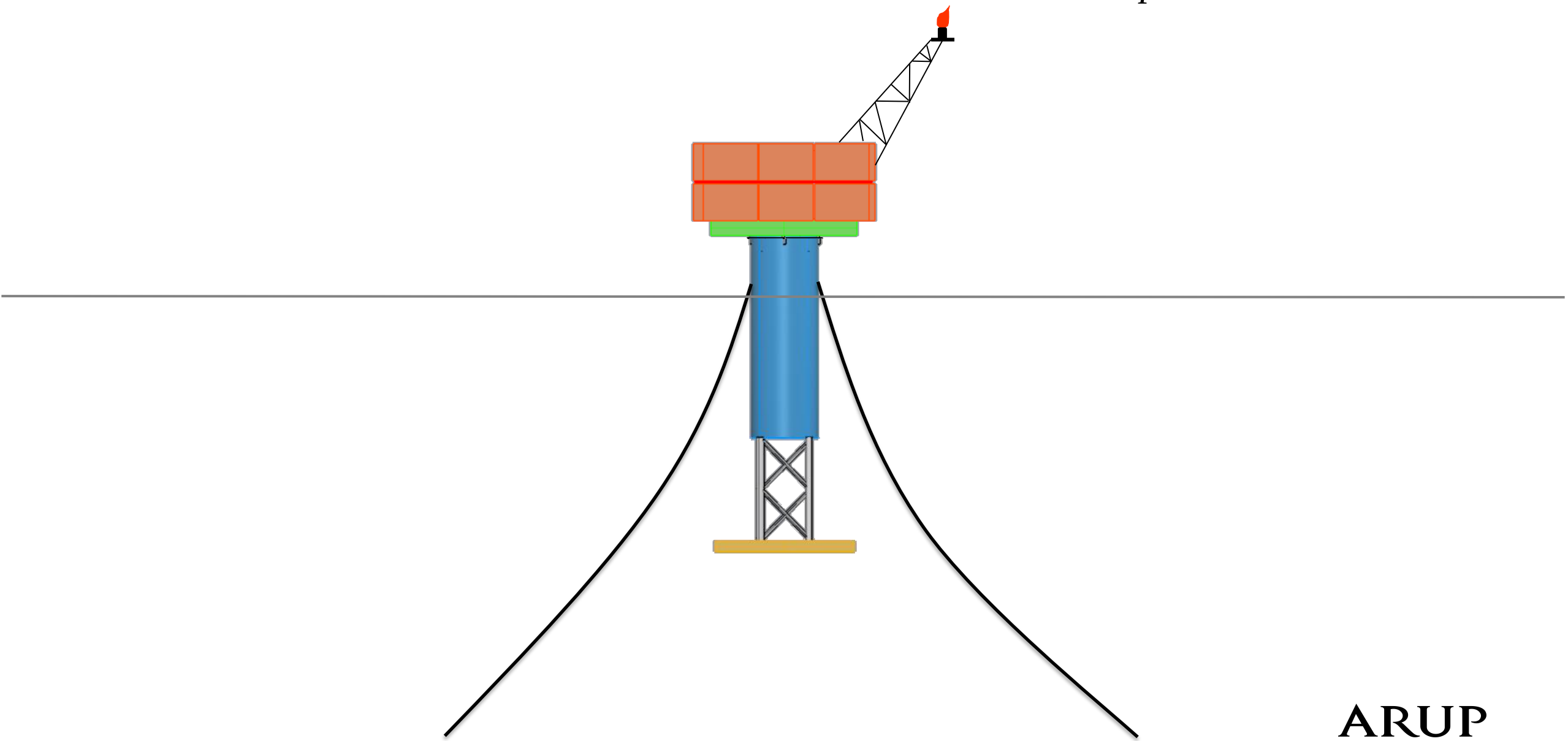
In-place



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Installation sequence (cont.)

Float-out

Lowering

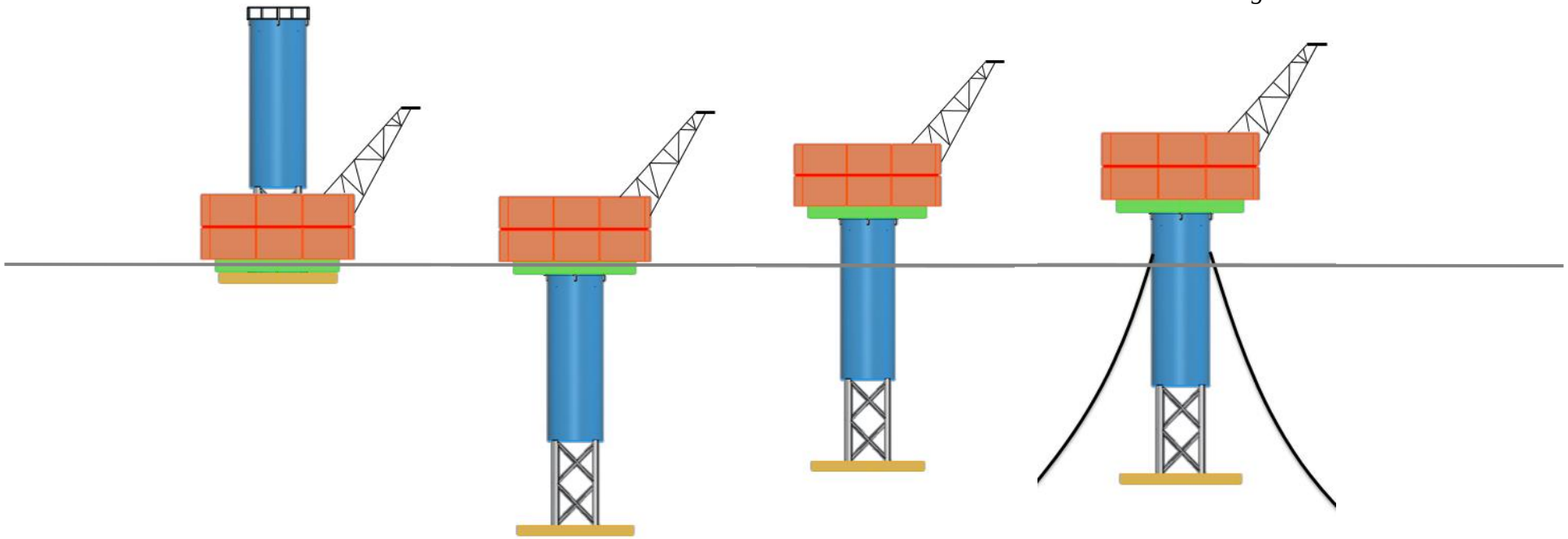
Ballasting Hard Tank, Soft Tank and Truss

Deck raising

De-ballasting Hard Tank

In-place

Hook-up & Commissioning



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Main Particulars

A typical deep-water Spar platform has been considered to estimate the initial sizing of the sub-structure for meeting the following criteria:

- ***Topsides weight:*** *~18,500t Topsides (with supporting barge)*
- ***Storage capacity:*** *up to 18,000 bopd capacity*
- ***Operational water depth:*** *up to 1,500m water depth*
- ***Centre well slot:*** *15m x 15m centre well slot*
- ***Air-gap:*** *Minimum ~25m in operational condition and remain positive in storm condition*
- ***Metacentric height (GM):*** *Positive in all conditions including Operational, Transportation & Installation*

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Spar Hull design

The basic hull dimensions have been calculated for the concept:

- **Barge deck (and sponsons if required)**

  - ✓ *Designed to form the primary support for the topsides modules*
  - ✓ *Provide adequate buoyancy during the Float-out stage and maintain appropriate freeboard*

- **Hard Tank & Soft Tank**

  - ✓ *Hard Tank: Provide adequate buoyancy during Operational condition to maintain sufficient air-gap*
  - ✓ *Soft Tank: Provide sufficient ballast (water or solid) during the Operational condition in order to maintain a positive GM.*

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Hull Dimensions

Barge Deck

- *Length/width: ~75 to 80m*
- *Height: 10 to 15m*
- *Well-bay to sit inside deck's slot OR a moon-pool*

Hard Tank

- *Diameter: 30 to 35m*
- *Length: 100 to 120m*
- *15-20 sq. m center well slot for buoyancy cans, conductors & risers*

Soft Tank

- *60-70 sq. m, 3-10m high*
- *20-25 sq. m center well slot to accommodate the risers*

Truss Structure

- *30-35 sq. m, 30-40m high*

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Weight control

Current ACE Spar configuration designed to handle a total payload of **~25,000t.**

Description	Weight (t)	XCG (m)	YCG (m)	ZCG* (m)
Topsides	9,000	0.00	0.00	174.00
Barge Deck	~9,500			
Wellhead bay				
Hard Tank				
Truss				
Soft Tank				
TOTAL	**~34,000**	**0.00**	**0.00**	**128.23**

*From bottom of the Soft Tank

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Hull Design features

Various factors affecting the Hull design:

- *Type of **Topsides facility** (production, drilling or both)*
- *Number of **conductors** (will dictate the center well and hence Soft tank and Deck size)*
- *Need for **storage capacity** (will drive the size of the Hard tank)*
- *Type of **tensioning** to be used for the risers (buoyancy cans, hydro-pneumatic, ram type)*
- *Presence of **VIV strakes** on the Hard tank (might lead to change in deck design)*
- ***Fabrication method** to be used (Vertical stacking preferred)*
- ***Installation sequence** (load-out or float-off)*
- ***Fabrication location** & capability (dry-dock, shipyard etc.)*
- ***Well-head bay** size & layout*

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Stability

As per ABS Rules for Floating Production Installations, Part 5B, Ch3 Sec 2,

the GM should remain positive during the Installation phase. GM achieved during different Installation stages:

- ***Float-off*** GM = 33m Freeboard: 10m Floating stability range: 32°
- ***Lowering*** GM = 57m Freeboard: 7m
- ***In-place*** GM = 3m Draught: 130m Air-gap: 25m

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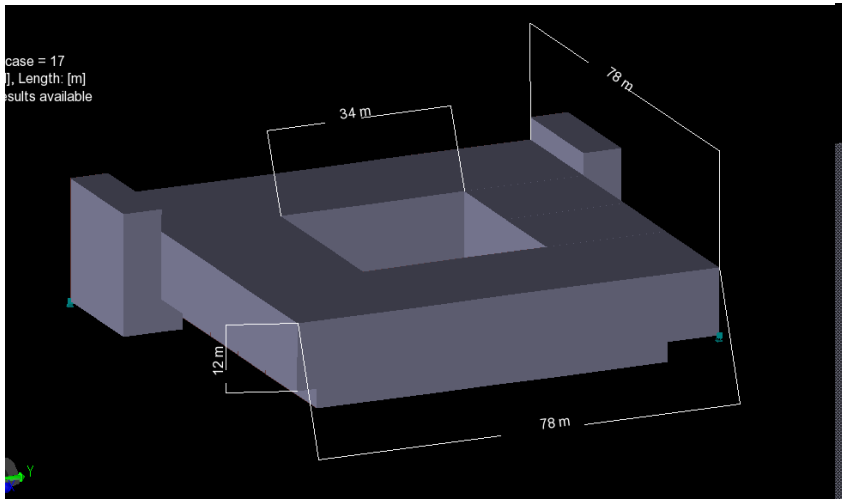
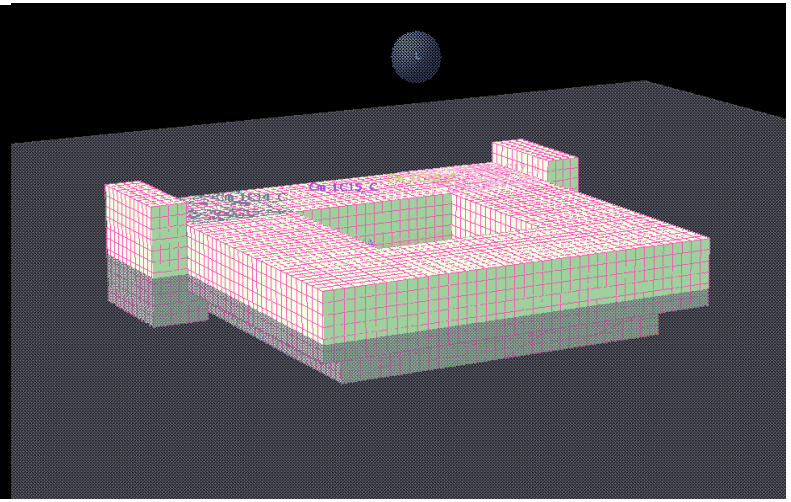
Float-out model (DNV Sesam)





- Structural model prepared in DNV Sesam module, Genie. The model comprised of barge deck, ballast compartments and auxiliary buoyancy aids in form of Sponsons
- Meshing done in Genie
- Stability check in HydroD
- Hard Tank accounted for as a point mass
- Trim ballast used to level the platform
- Required freeboard, stability range and positive GM achieved

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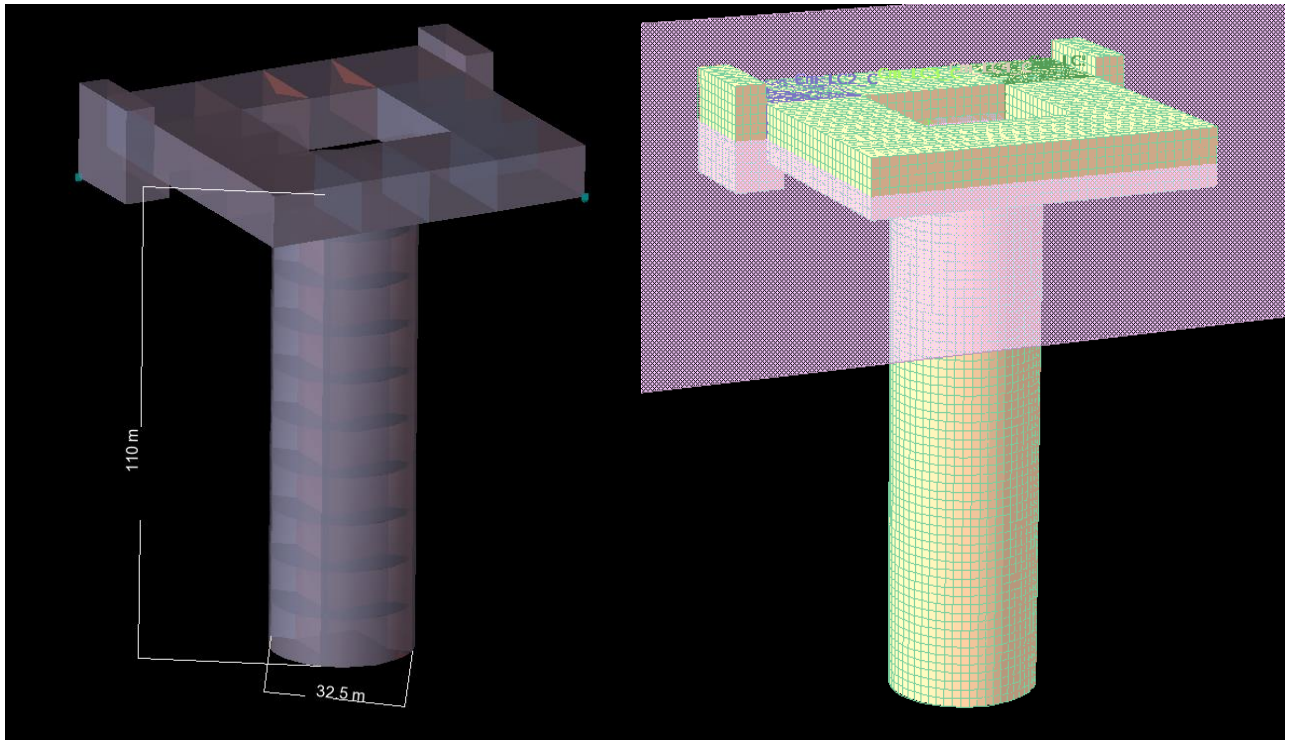
Lowering model



- Structural model was prepared in Genie. Model comprised of hard tank, barge deck, ballast compartments and auxiliary buoyancy Sponsons
- Stability check done in HydroD
- Trim ballast used to level the platform
- Required freeboard and positive GM achieved

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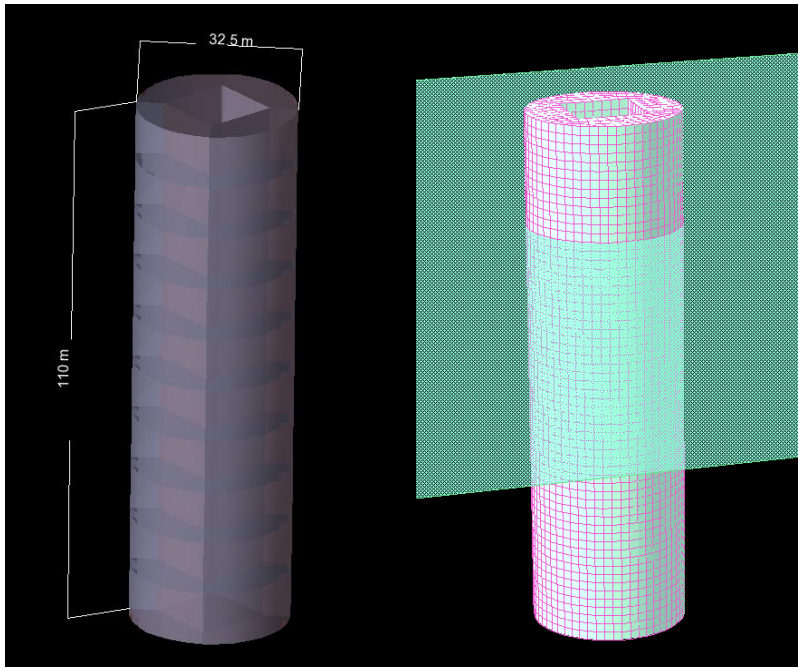
In-place model



- Structural model was prepared in Genie. The model comprised of hard tank and ballast/product compartments
- Meshing done in Genie
- Stability check in HydroD
- Required air-gap and positive GM achieved
- Only Hard Tank was modelled to get the correct water-plane area

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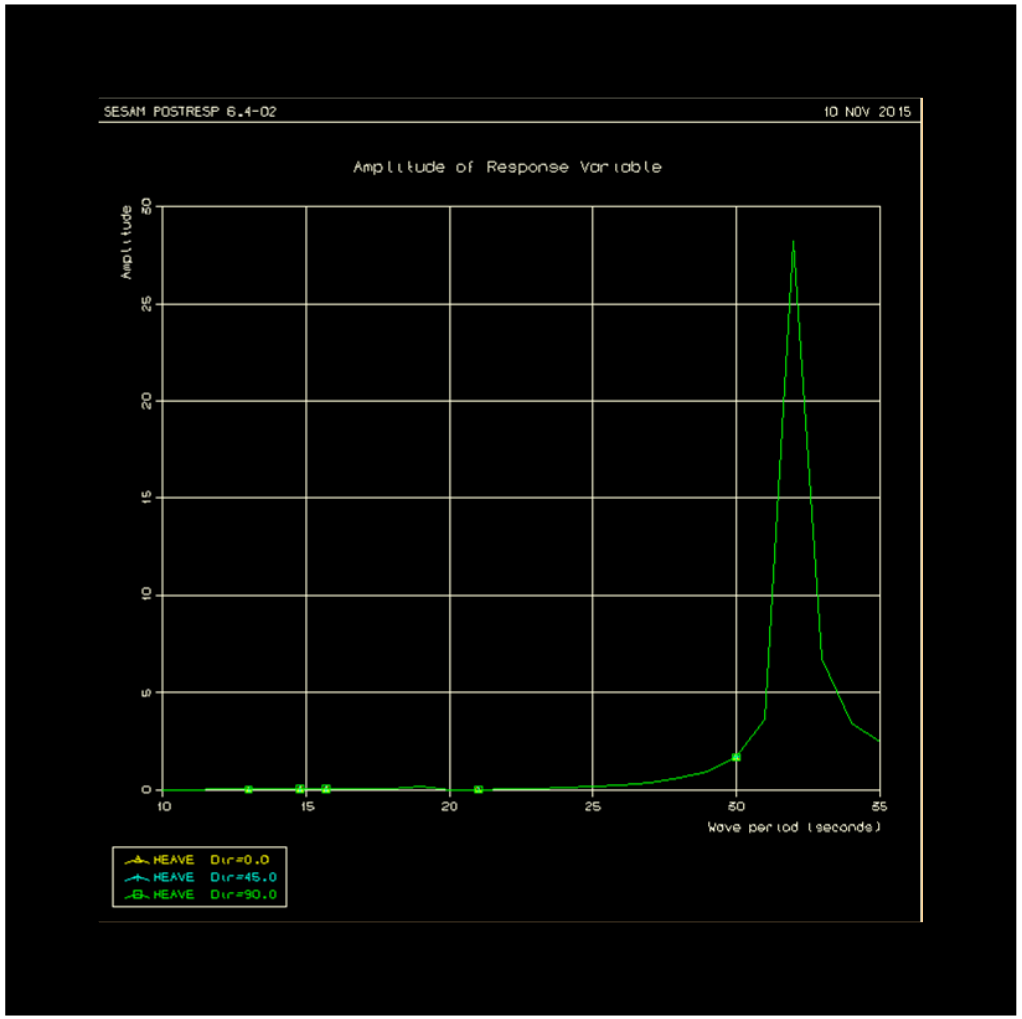
Motion Response



Frequency domain analysis was carried out to estimate the natural frequencies and the peak response of the platform using DNV Sesam modules Hydro and Wadam.

Natural Frequency:

- *Roll: 92.4 sec*
- *Pitch: 92.3 sec*
- *Heave: 32.1 sec*

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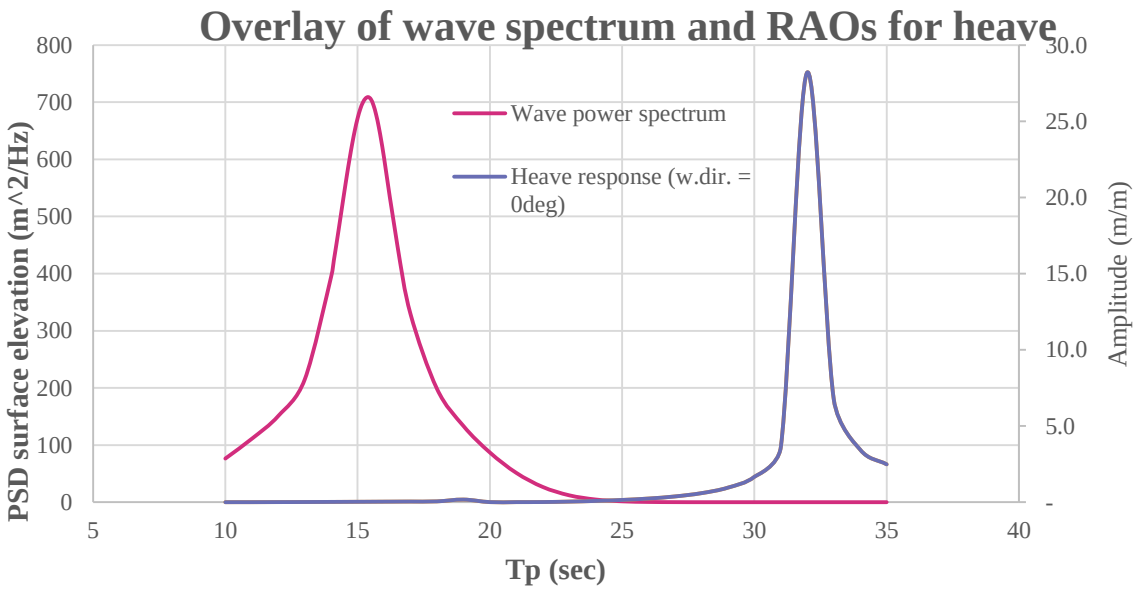
Motion Response (cont.)

Motion response checked in a Gulf of Mexico 100 year RP storm condition. Similar or less worse met-ocean conditions for WA region.

Hs = ~16 m Tp = ~15 sec



Heave natural frequency is sufficiently far from crest of the wave spectrum and hence gives a peak response of upto **0.6m.**

Pitch and Roll motion response are minimal.

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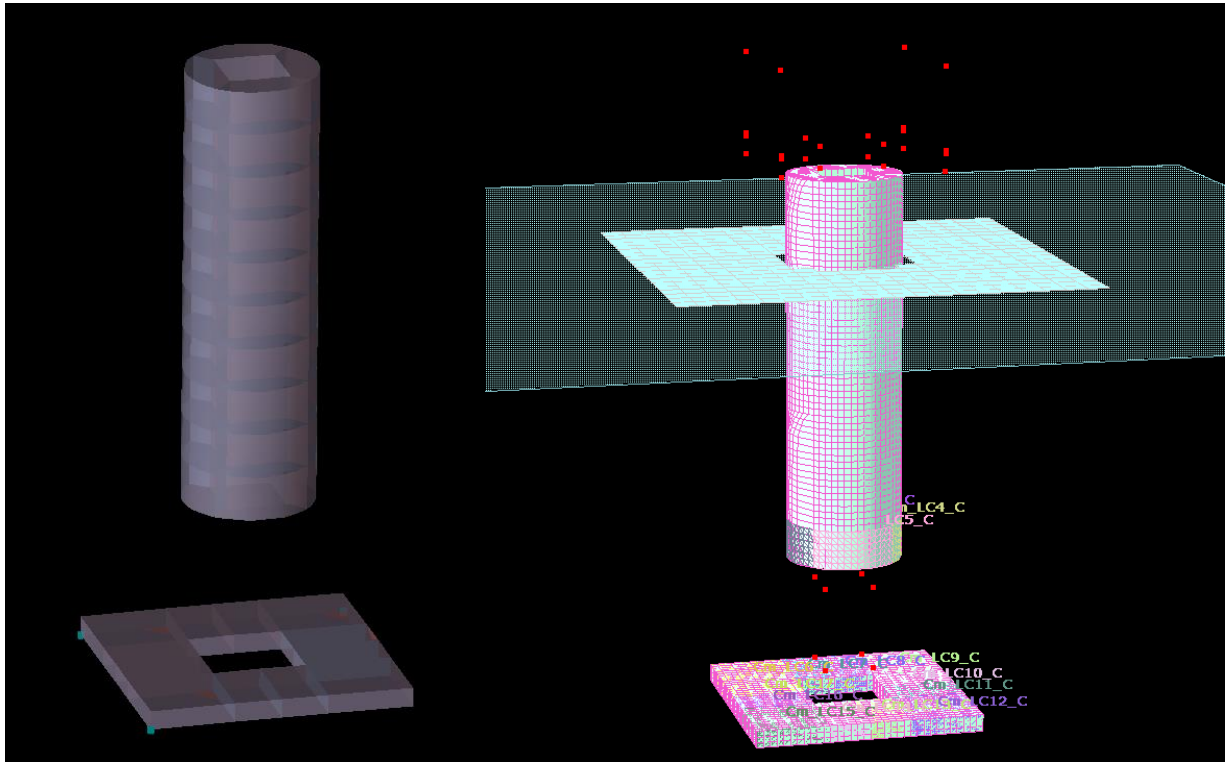
Motions model



- Genie model was used with Soft Tank for In-place condition
- Total mass of the structure was distributed using point masses to account for the inertia including the Topsides, barge deck and truss members
- Permanent water ballast in soft tank has been modelled in HydroD

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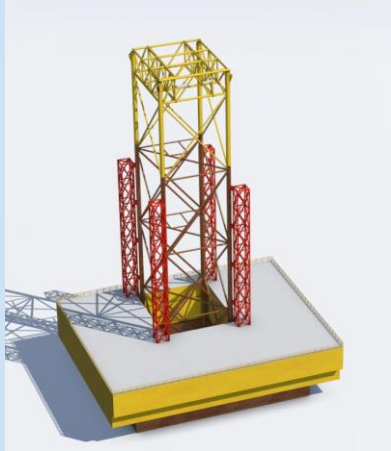
Construction advantages

Conventional Spar	ACE Spar
• Built in half or quarter sections and joined before transporting to the offshore site. 	• Vertical stacking construction configuration similar to what is used for constructing oil terminal/refinery oil storage tanks. 
• Top-tensioned riser system or buoyancy cans hook-up and commissioning offshore.	• Top-tensioned riser system or buoyancy cans can be pre-commissioned during the fabrication stage onshore, saving significant costs for offshore installation.
• Conventional fabrication method used of connecting structure blocks horizontally.	• Strand Jacks to be used to construct and erect the hard tank vertically.

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Contents

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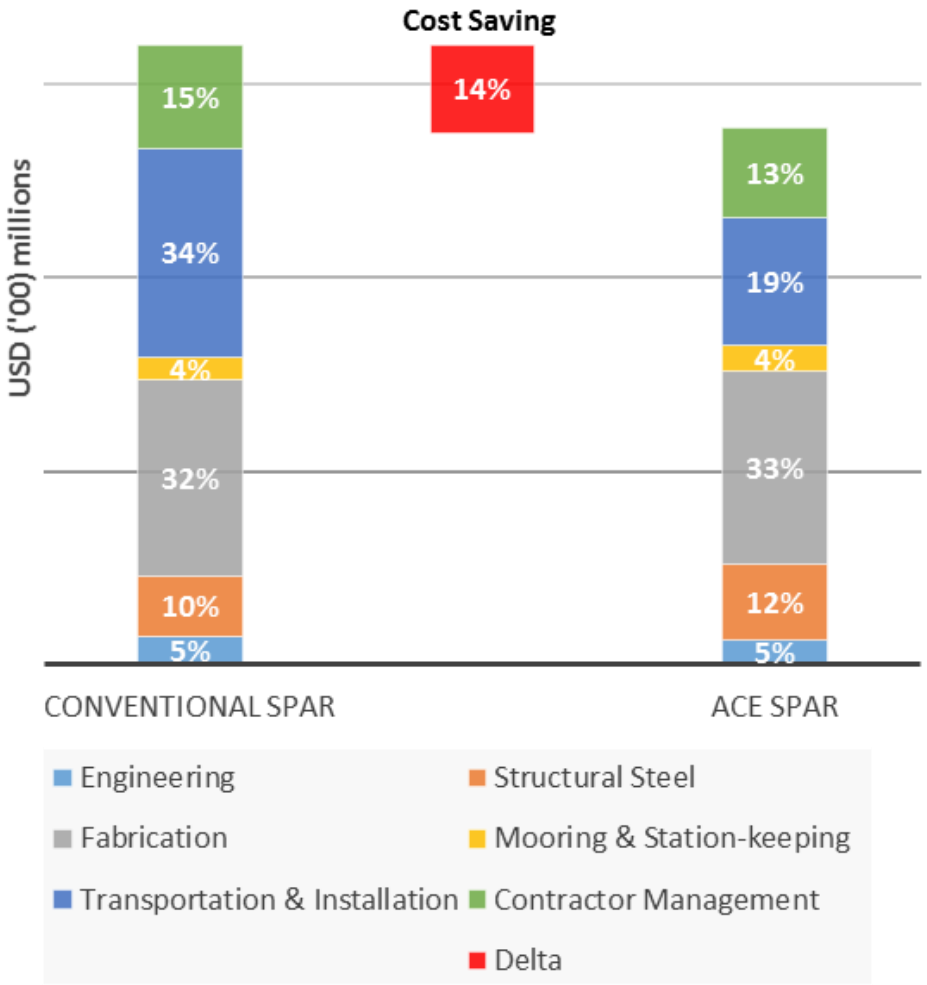
Cost break-down

A bottom-up cost estimation and comparison has been carried out for the ACE Spar platform.



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Cost – Transportation & Installation

The T&I costs can be reduced significantly compared to a conventional deep-water spar platform.

T&I phase	Conventional Spar	ACE Spar
Sub-structure tow	Semi-submersible vessel	Semi-submersible vessel
Sub-structure installation	Semi-sub vessel, tugs	Semi-sub vessel, tugs
Topsides load-out	Barge	Semi-sub vessel
Topsides tow	Barge	Semi-sub vessel
Topsides installation	Barge, HLV, tugs	Semi-sub vessel, tugs
Hook-up & Commissioning	HLV, tugs	Tugs

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Further work..

- ***Model Testing*** *for motion response assessment and moorings*
- ***Effect of viscous drag*** (soft tank & additional heave plate if required) on the motion response of the Spar
- ***Mooring design*** including dynamics of mooring lines and a coupled analysis to estimate the spar motions due to mooring stiffness
- ***Effect of different type of TTRs*** (top-tensioned riser) on the design of Spar
- ***Transportation motion response*** of the Spar
- ***Refine the Structural design*** to reduce the amount of steel required
- Stability & motion assessment for a ***CG offset***
- Sensitivity checks on ***Auxiliary buoyancy*** requirement in form of Caissons
- Effect of current; requirement & design of ***VIV strakes*** on overall Spar design

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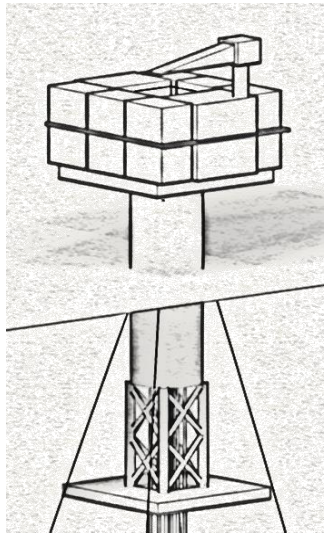
Summary – Why ACE Spar?



- **Self-Installing**
- Less intensive **offshore campaign**
- **Reduced requirement of specialist vessels**
- **Un-interrupted deck space**
- **Re-locatable De-commissionable**
- **Improved constructability**
- Enhanced **Project Economics**

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Thank you

Questions?

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