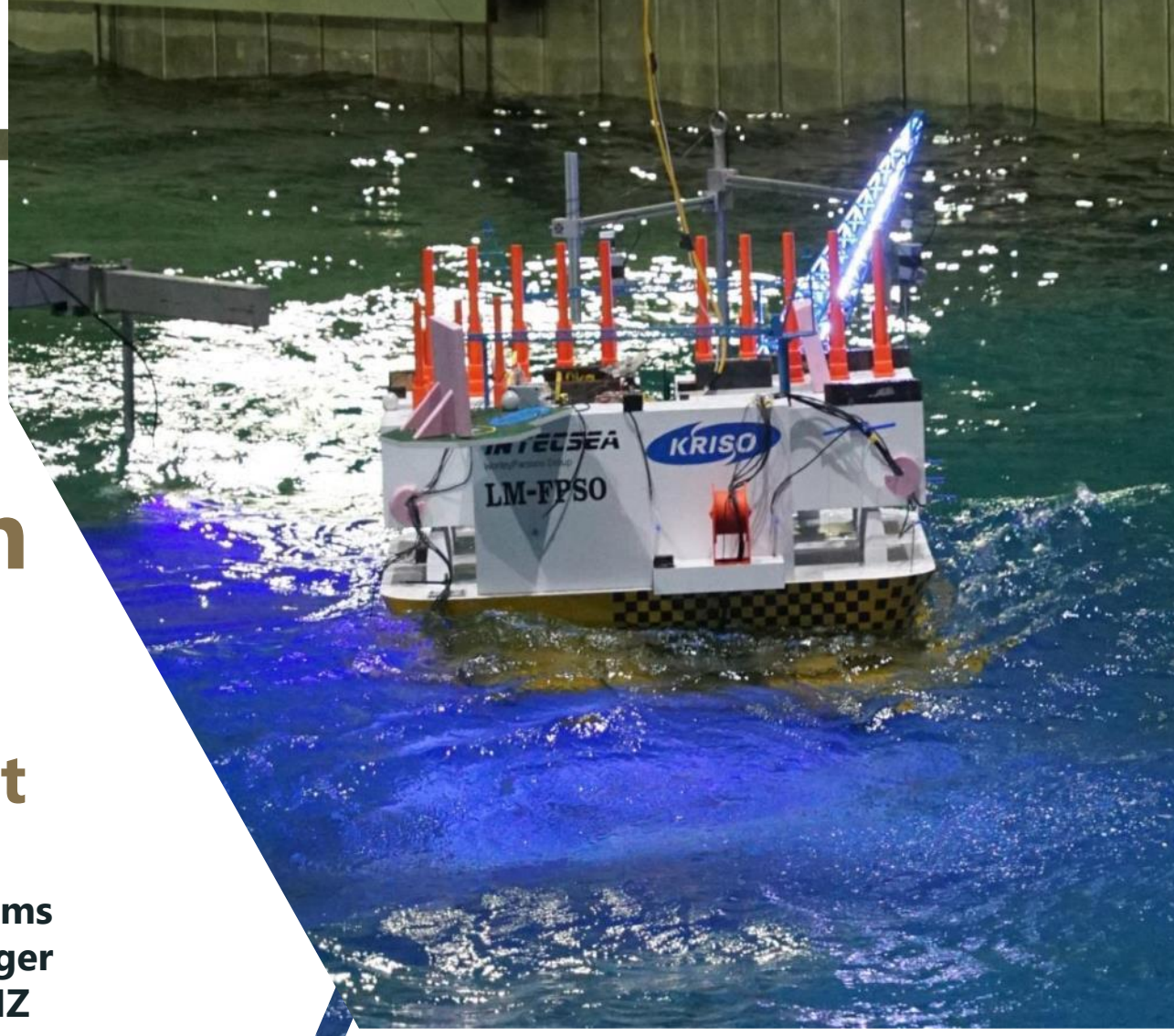
The Low Motion Floater (LMF)

Low Motion = Low Cost



Chunfa Wu, Vice President Floating Systems
Alaa Mansour, Marine Engineering Manager
Yuriy Drobyshevski, Floating Systems, ANZ

Evening Technical Meeting:
Light Well Intervention, Flowlines Buckle Management and the Low Motion Floater
Wednesday, 9th August 2017 ✦ Parmelia Hilton Hotel (Argyle Room), Mill St. Perth

SUT Society for Underwater Technology

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Outline

- **Pros and Cons of Conventional FPSO**
- **The Low Motion Floater (LMF)**
  - Design
  - Performance
  - Construction, Transportation & Installation
  - Risks and Mitigation Measures
  - Main Technical and Economical Advantages
- **Application to FLNG**
- **Development Status**

Pros and Cons of Conventional FPSO

Pros:

- High oil storage capacity
- Suitable for remote fields with little or no infrastructures
- High topside payload capacity
- Relatively straightforward fabrication and installation; quayside integration
- Most popular FPS with more than 60% market share

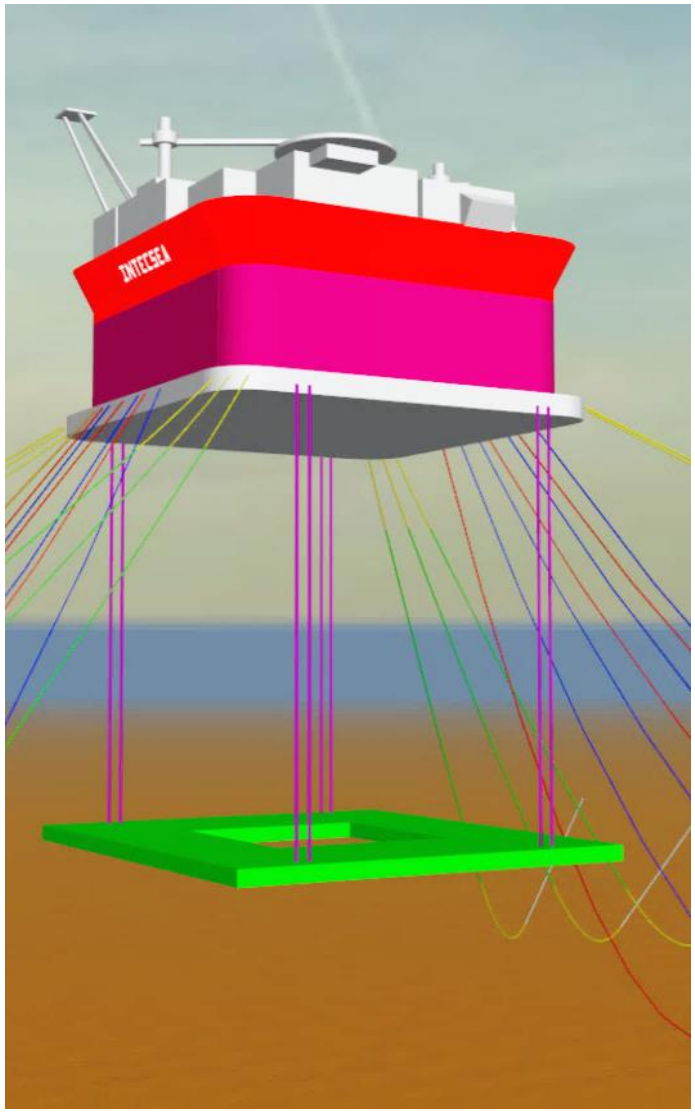
Cons:

- Unsuitable for SCRs except of very mild environment and narrow range of water depths ➔ Limited riser solutions
- Unsuitable for TTR and requires a separate Dry Tree Unit if direct vertical access to wells is needed
- Require turret and swivel in medium and harsh environment ➔ Complex component, design limitations, cost and schedule impact
- Most of the above are caused by: **high heave, roll and pitch motions**

LM FPSO can preserve the pros and eliminate the cons

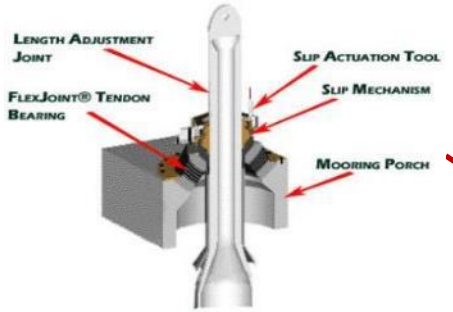
Benefits of Low Motion

- Enable use of SCRs : reduced limitations on riser size, simplified filed layout and improved integrity
- Enable use of TTRs, if desirable on the floater
- Eliminate the need of turret and swivel
- Reduced topside main structural steel due to reduced accelerations
- Reduced sloshing in ballast and storage tanks
- Improved operability: better efficiency in topside processing and better helicopter operability
- Improved habitability: less motion related effect on offshore personnel



The LM FPSO Design

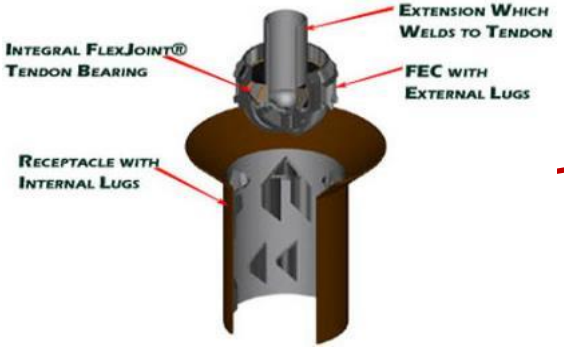
All Components are field proven



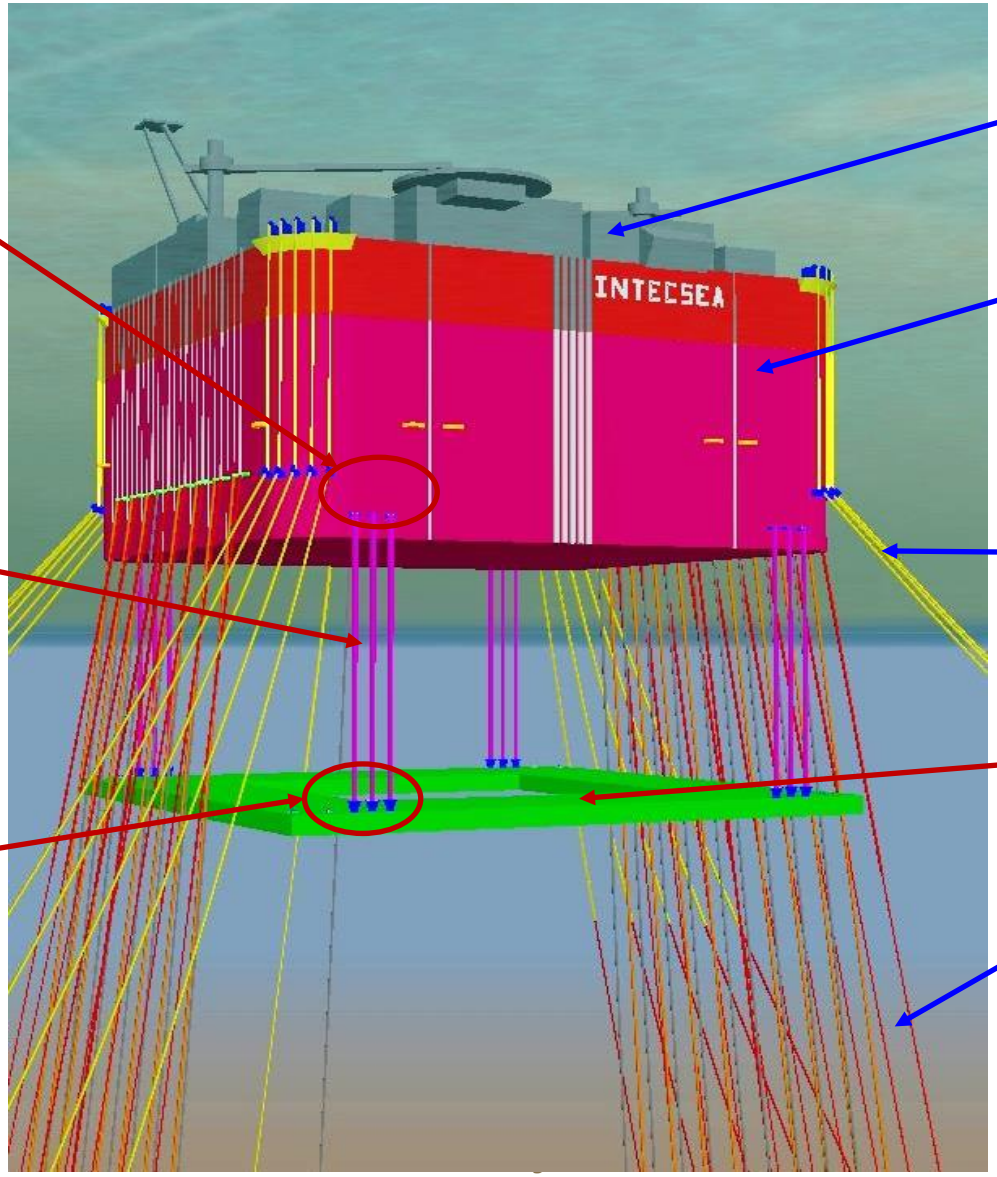
Tendon Top Connector

Courtesy of www.oilstates.com

Short Tendon Pipe
No couplings



Tendon Bottom receptacle



Conventional Topside

Conventional hull

Conventional Mooring

Solid Ballast tank (SBT)

SCRs / Umbilicals

The LM FPSO Design Features

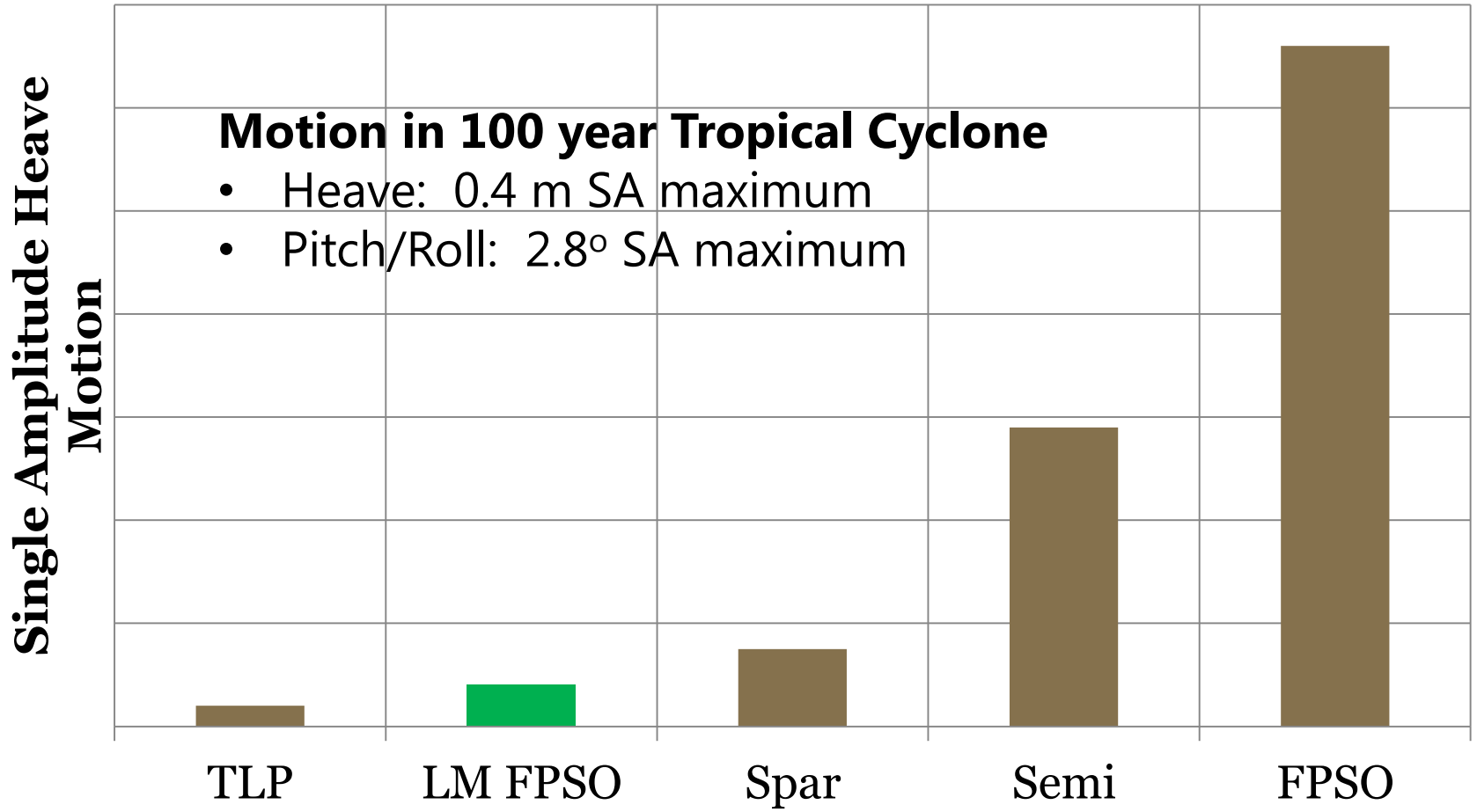
- Square or Rectangular shaped hull provides:
  - Flexibility of topside arrangement – more conventional layout, ability to adopt conventional FPSO topside modules
  - Control over the hull width ➔ enables large storage capacity, still to fit within dry dock requirements
  - Lower VIM response (compared with round shape) ➔ better mooring and riser fatigue
- Modular topside allows for easy quayside integration
- Hull is based on stiffened plate design for easy fabrication
- Tendon system used for Solid Ballast Tank (SBT): robustness, large load carrying capacity, flex-joints at top and bottom connectors

How Are Low Motions Achieved?

- SBT mass:
  - Provides high stability (high GM) => less number of compartments, reduced Low Frequency roll / pitch motions
  - Maintains positive tendon tension in all design conditions
  - Ensures full coupling with Hull in heave, roll and pitch (wave frequency)
  - Ensures full coupling with Hull in surge, sway and yaw (low frequency)
- SBT mass and Added mass
  - Long heave, roll and pitch natural periods
  - Significantly lower heave, roll/pitch motions
- Relative motion in surge, sway and yaw
  - Limited to first order (wave frequency)
  - Much less than TLP hull-to-foundation relative motions

➔ Low motion is due to mass & added mass of SBT.
Independent control of motion and offsets

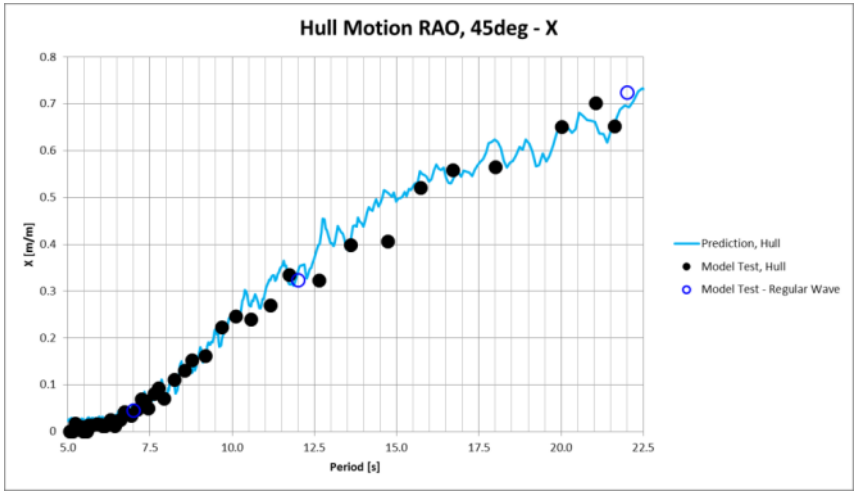
How Low is "Low Motion" Response ?



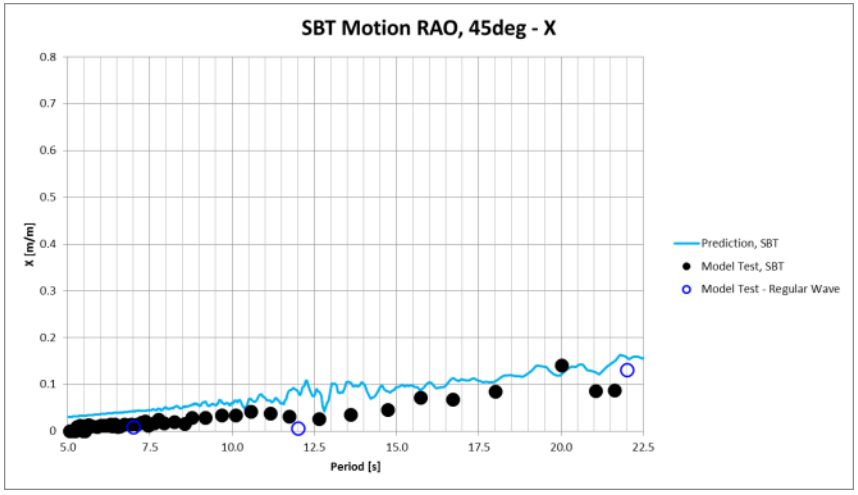
LMF motion can be almost as good as TLPs and is adjustable

Model Testing – Motion RAOs

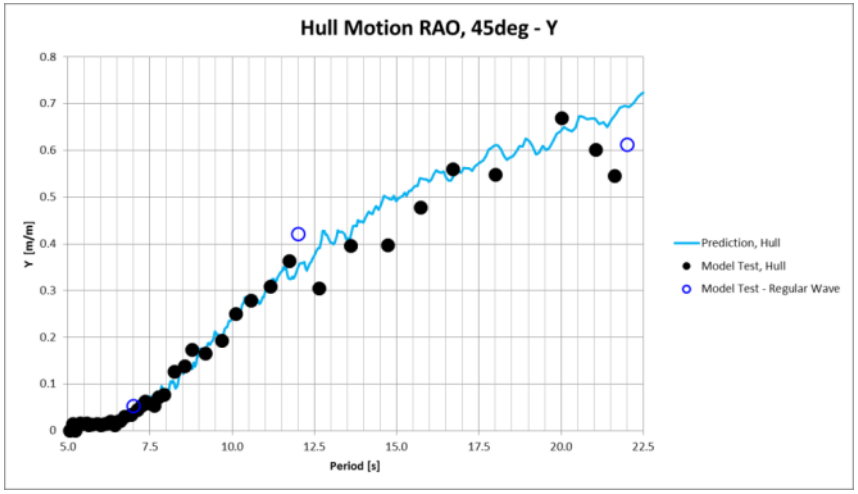
Surge



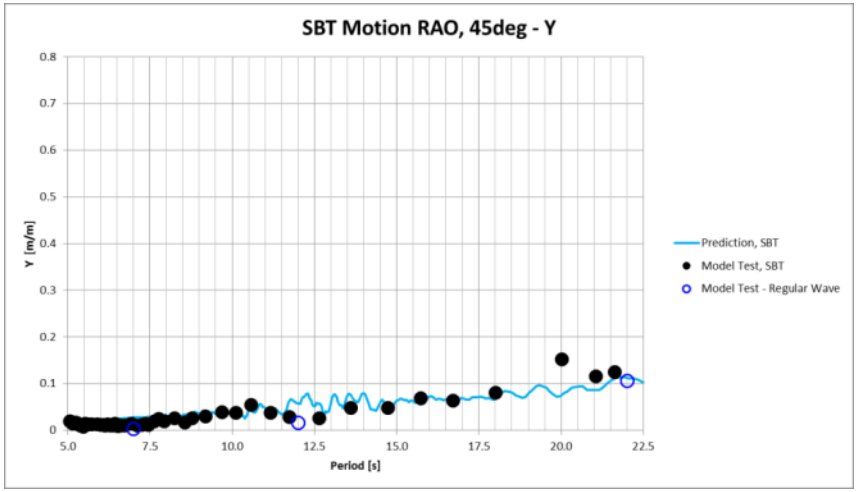
Surge



Sway

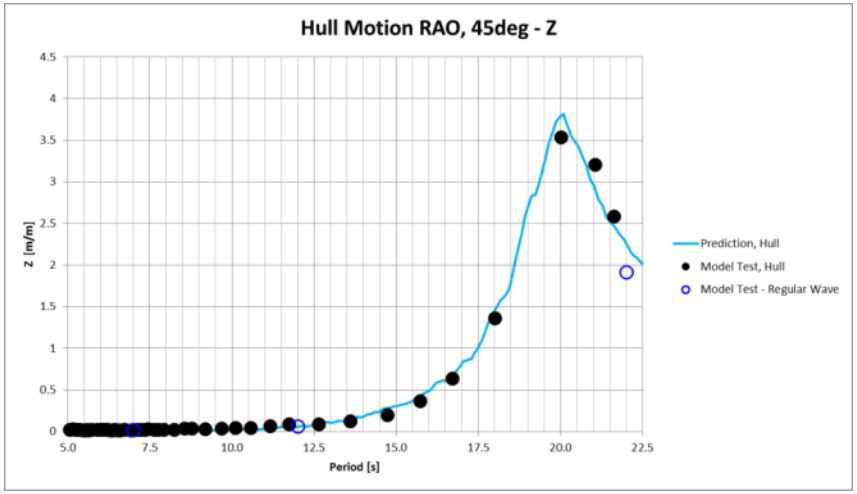


Sway

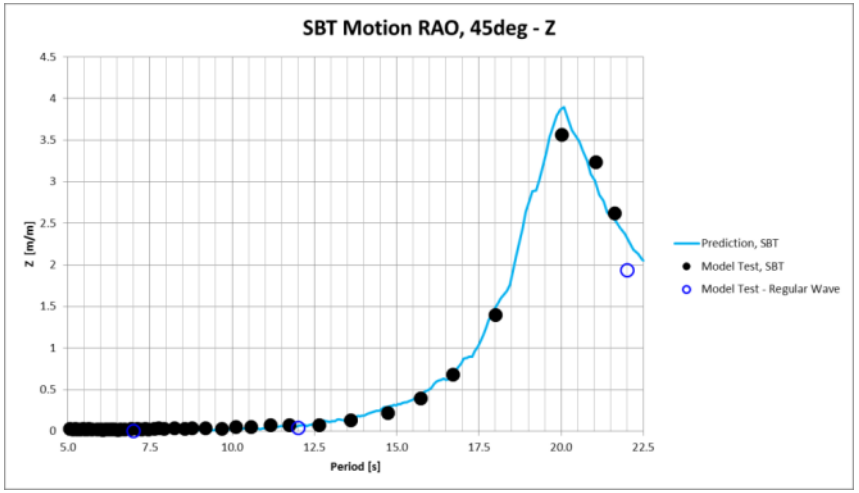


Model Testing – Motion RAOs

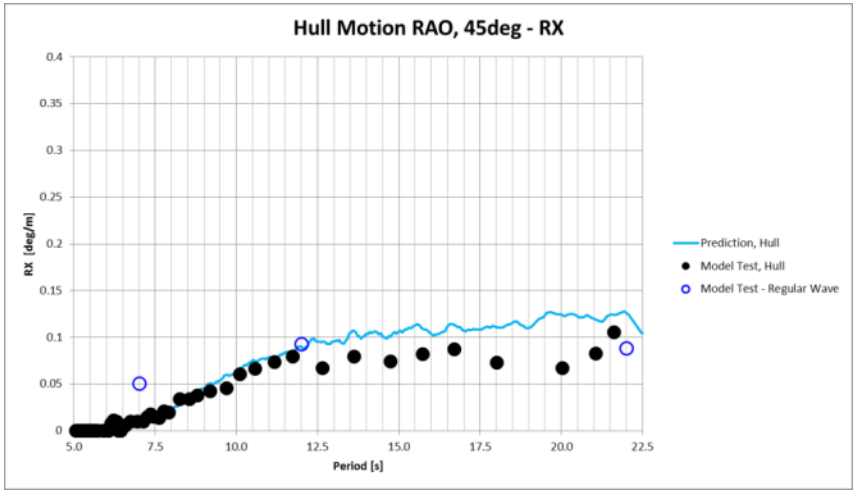
Heave



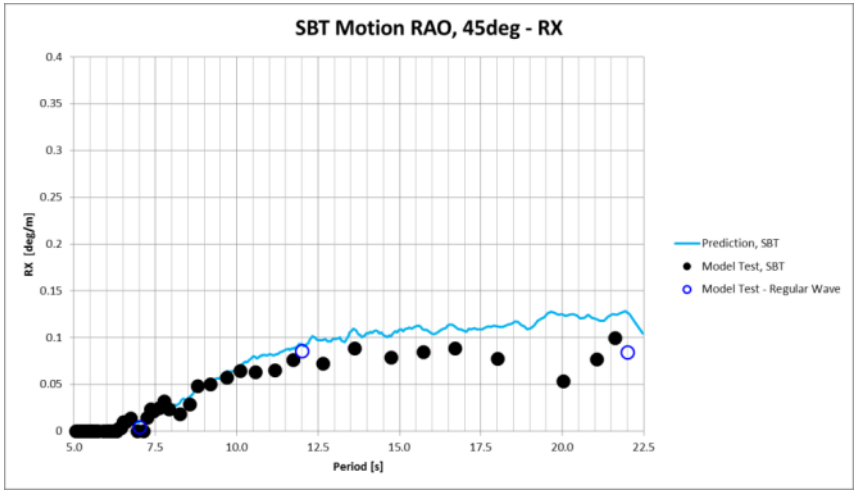
Heave



Roll

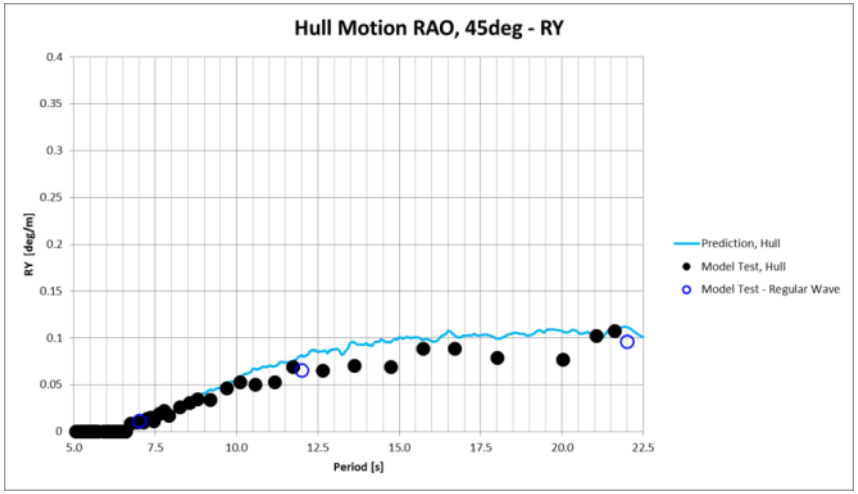


Roll

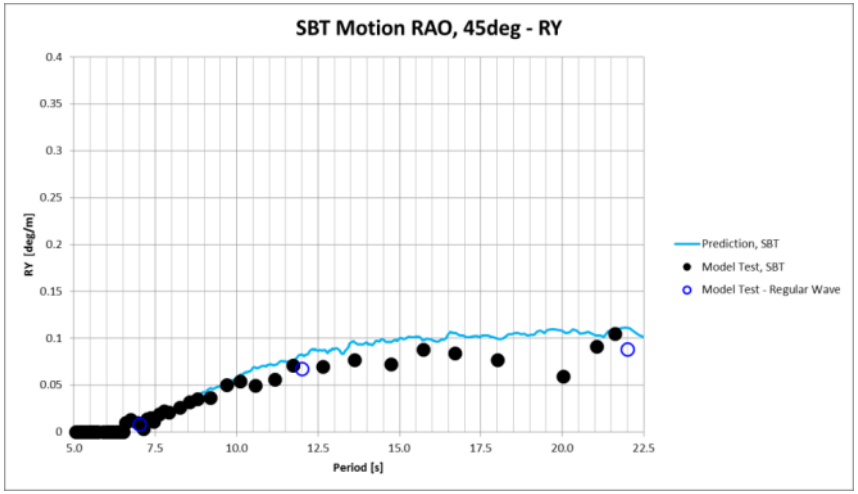


Model Testing – Motion RAOs

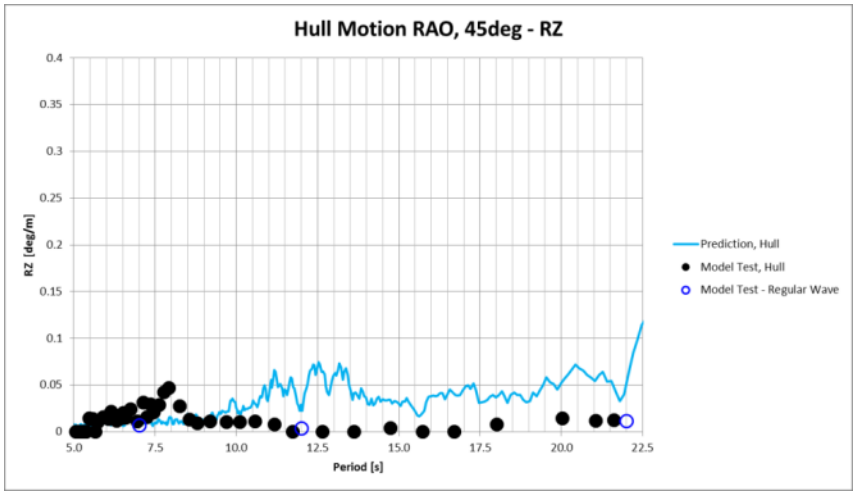
Pitch



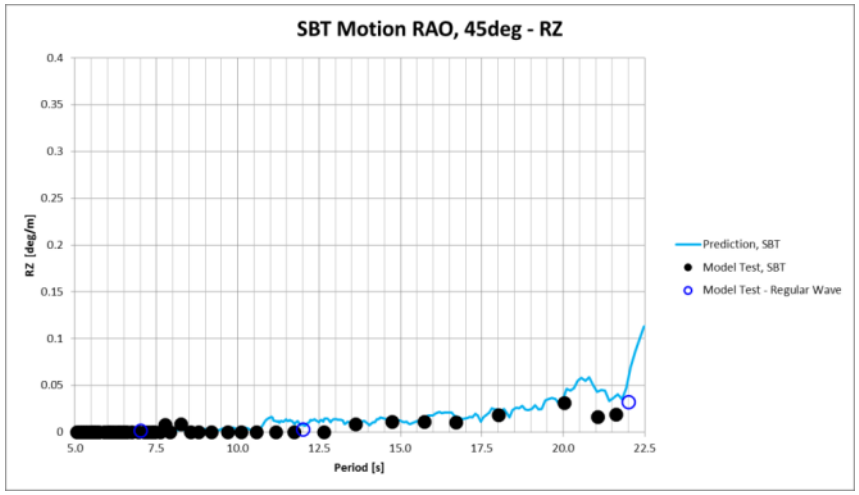
Pitch



Yaw

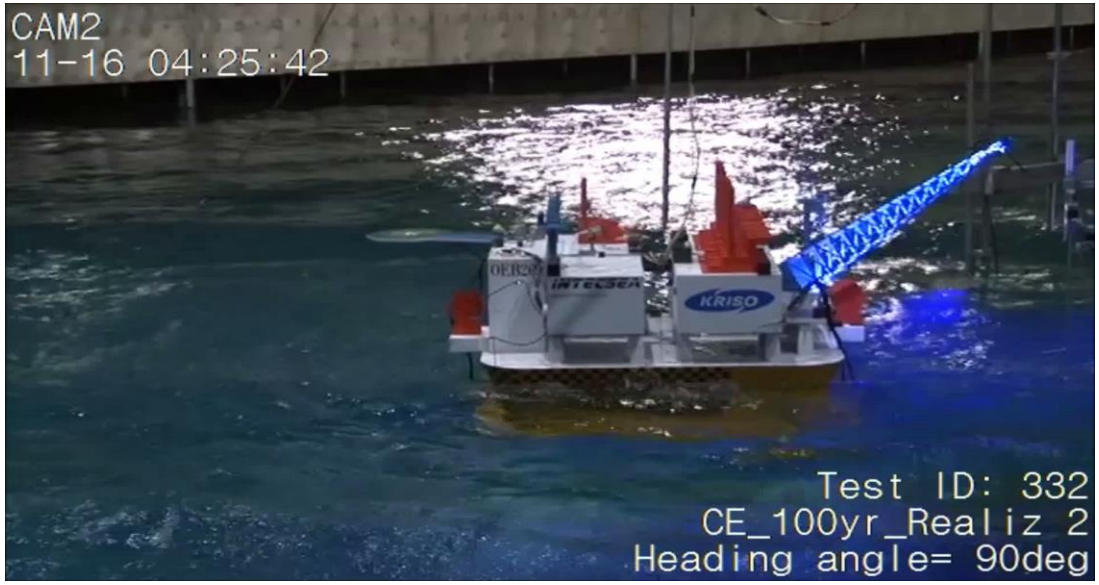


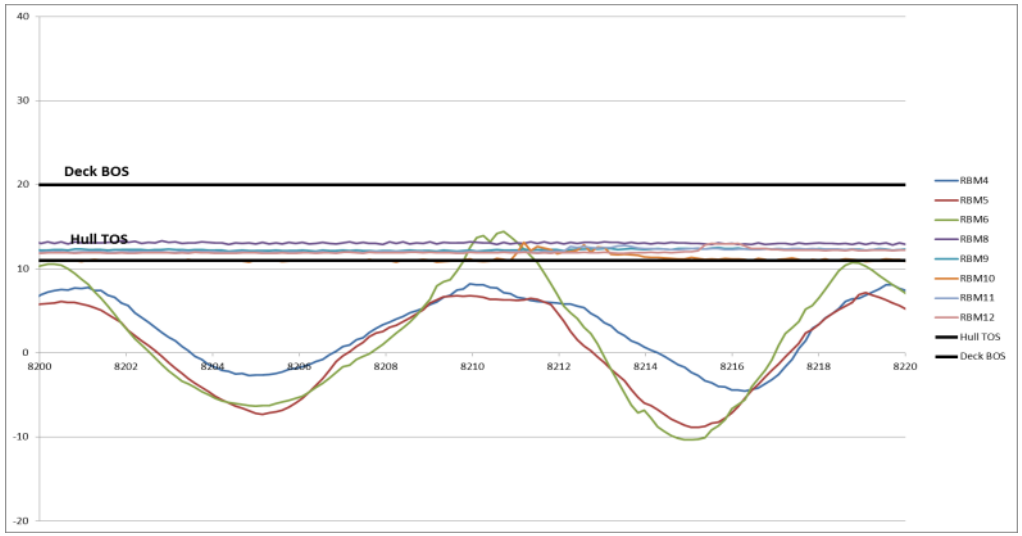
Yaw



Model Testing Overview – Green water

100yr 90deg

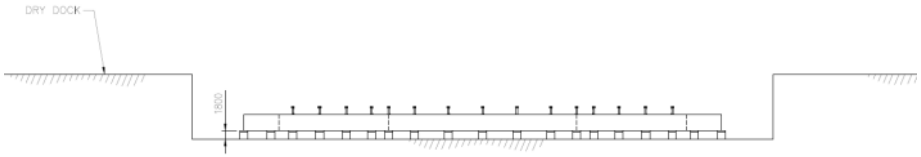




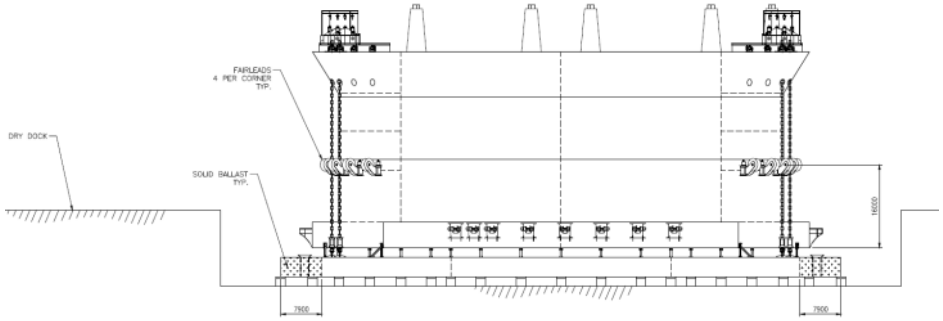
LMF Fabrication, Transportation and Installation

- Constructability of the SBT and Hull was reviewed and confirmed by a major Korean shipyard
- Optimum construction method: Modular fabrication and dry dock assembly
- Fabrication, transportation and installation sequence

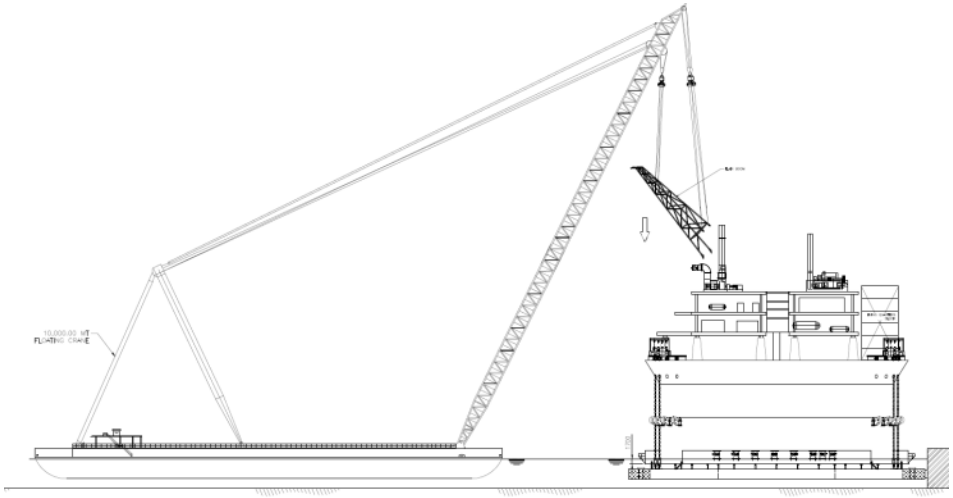
LMF Fabrication, Transportation and Installation



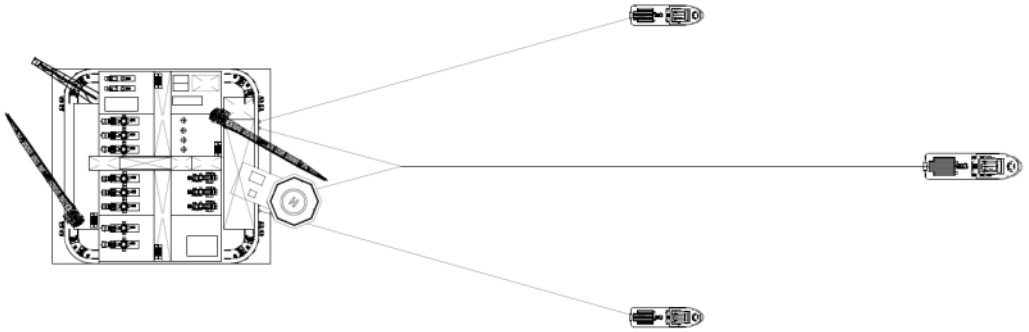
SBT is fabricated in the dry dock



Hull is assembled on top of the SBT in the dry dock

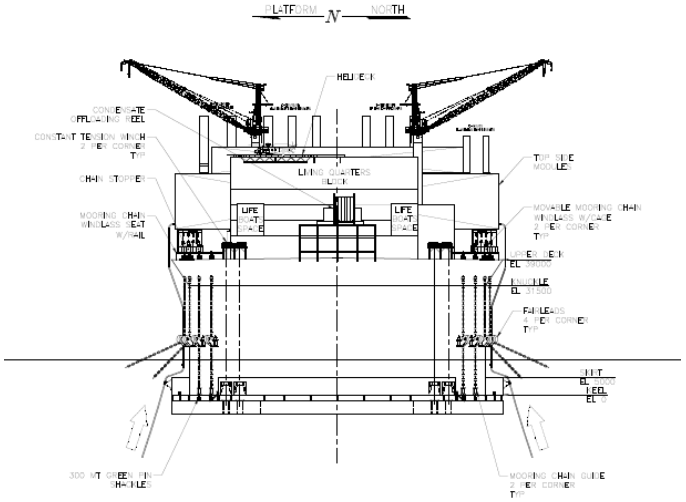


Topside modules are integrated at quayside



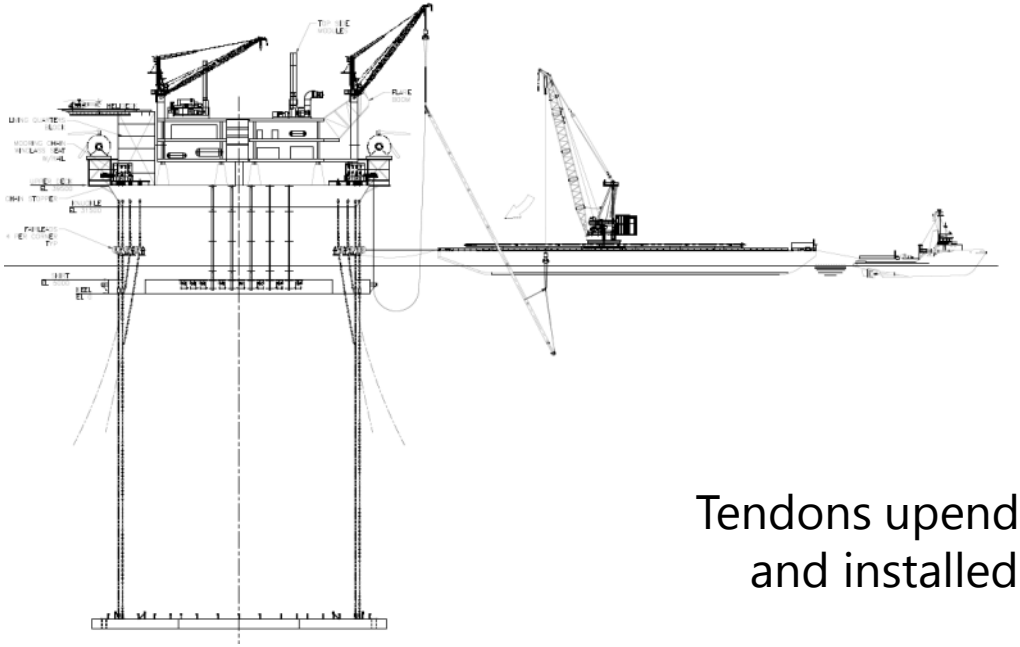
The platform is wet-towed to installation site

LMF Fabrication, Transportation and Installation

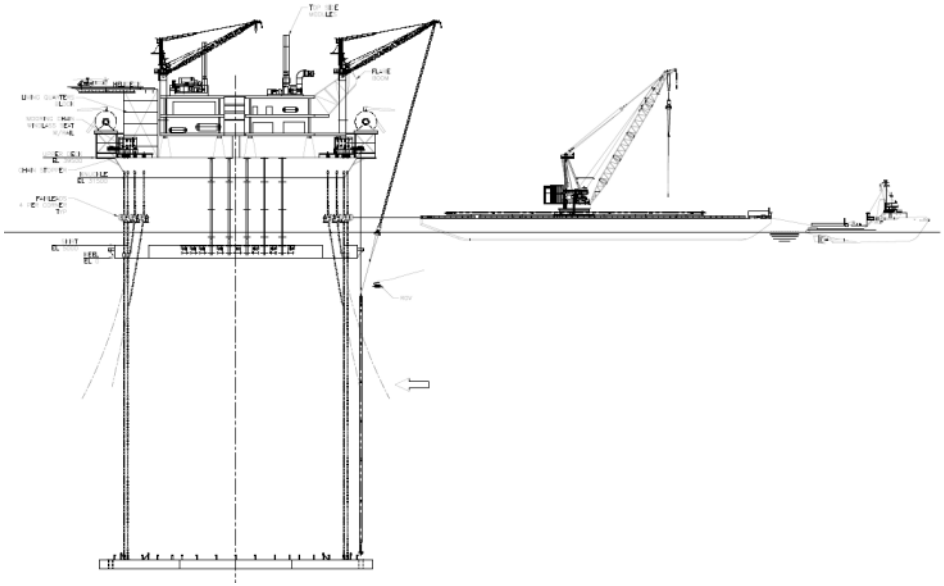


8 windlass/chains are used to lower the SBT

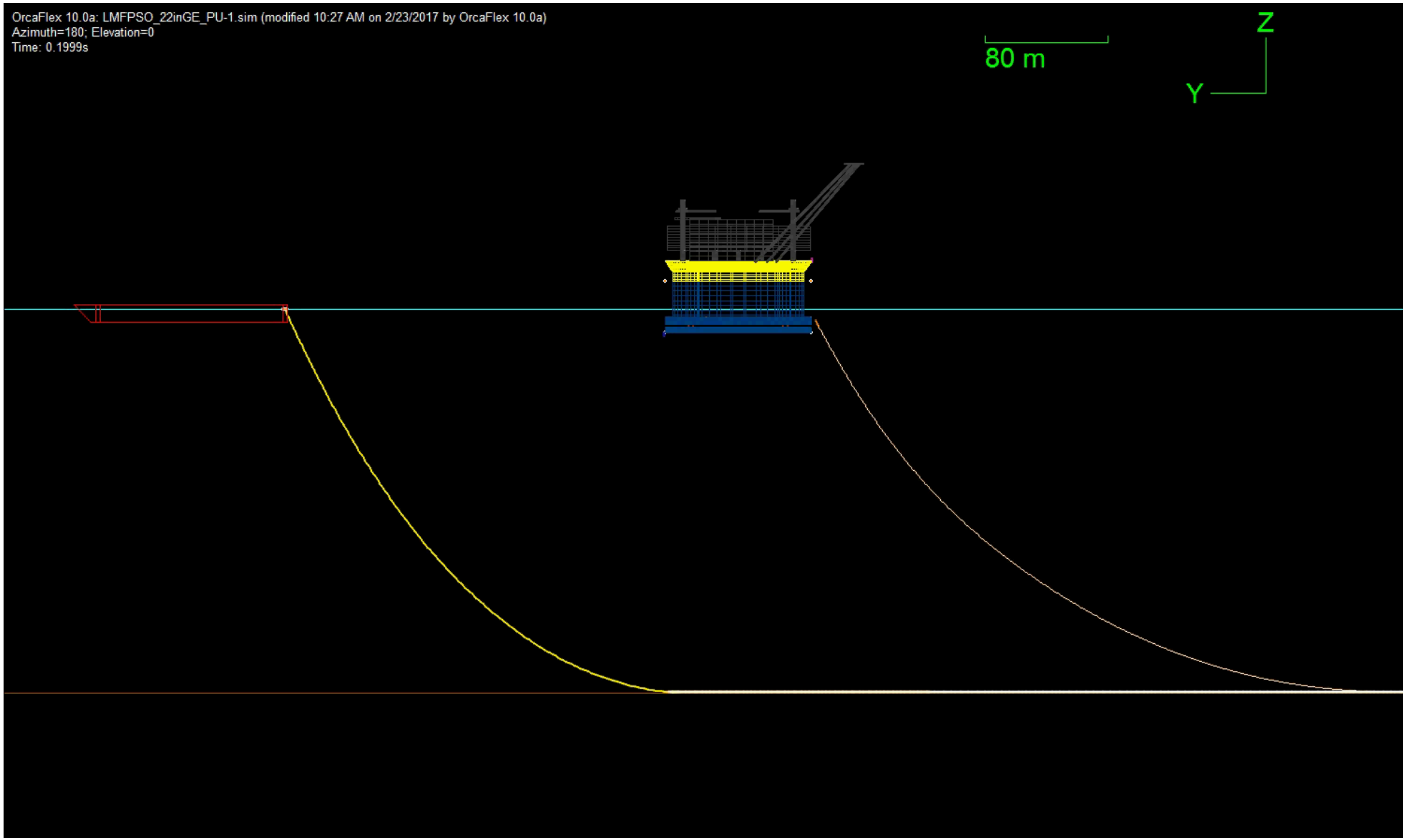
8 of 16 Moorings and pre-laid risers are installed



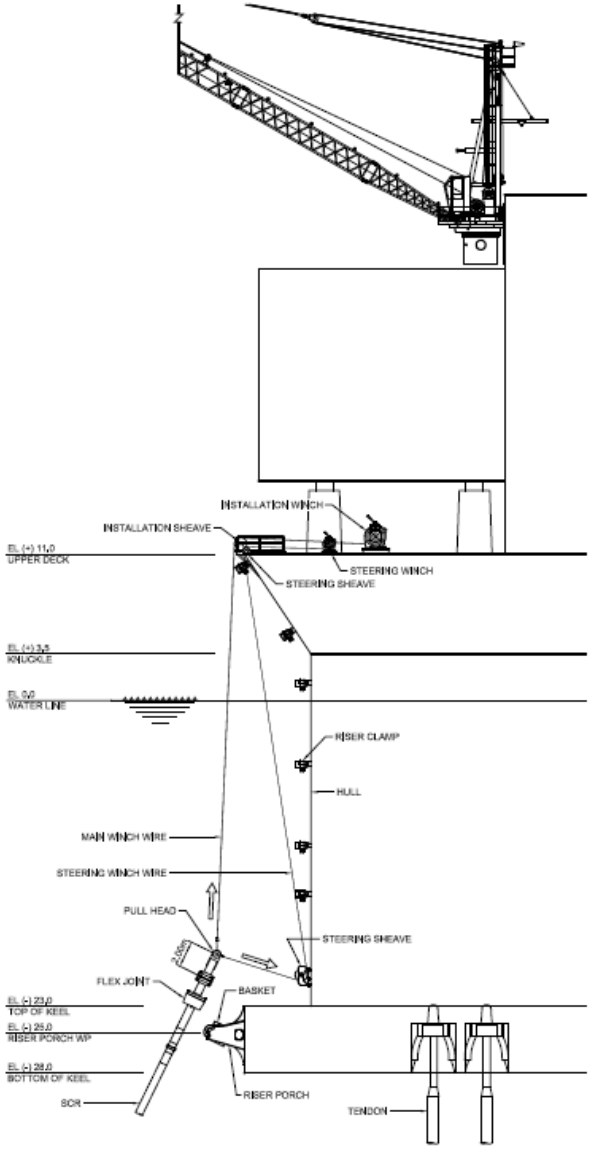
Tendons upended and installed



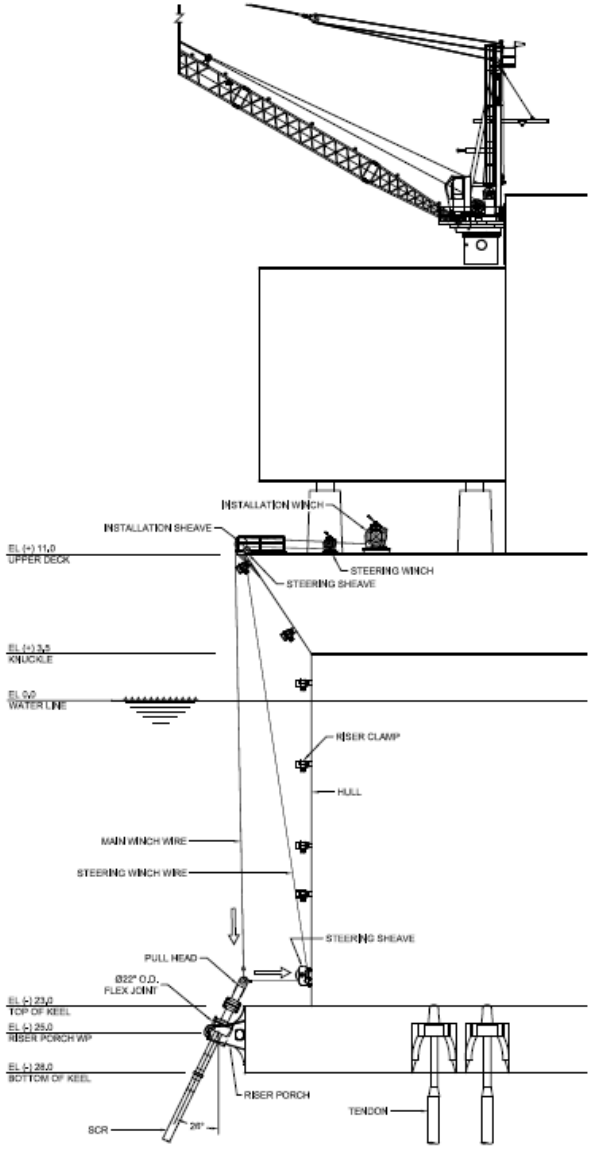
SCR Keel Haul



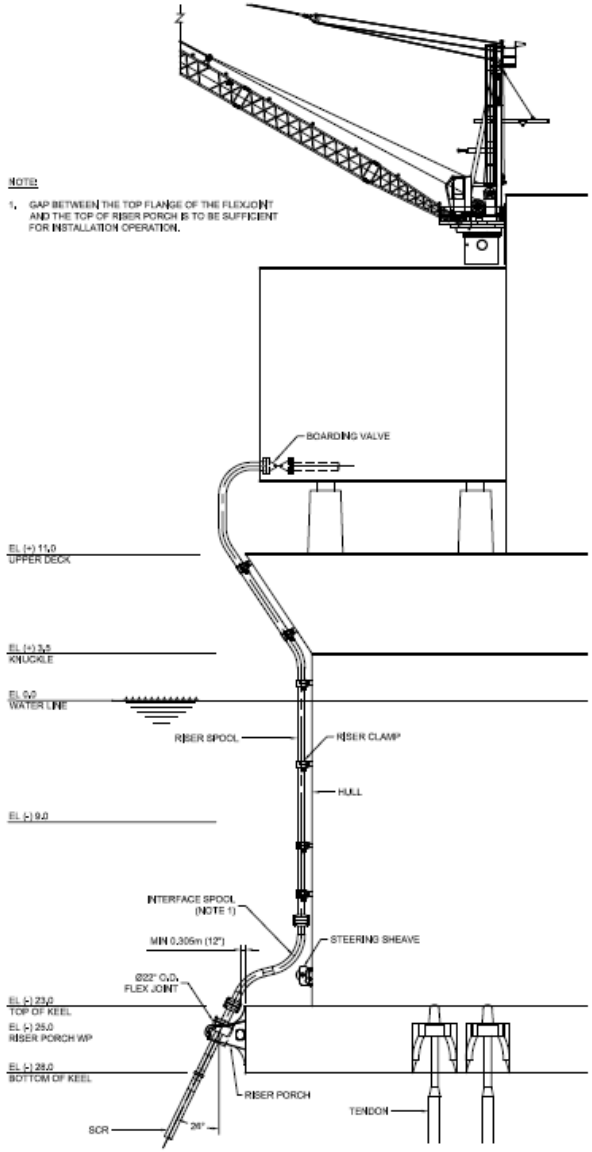
SCR Pull In



RISER PULL-IN
(STEERING WINCH WIRE ATTACHED)



RISER PULL-IN
(FLEXJOINT SEATING IN BASKET)



RISER INTERFACE SPOOL TIE-IN TO TOPSIDES

Tendon Lifting – Installation Options

Courtesy of www.jumboship.nl

Risks and Mitigation Measures

- Fabrication :
  - Hull width may limit available fabrication facilities (dry docks)
  - Hull width may require crane with extra reach for lifting modules on the hull. Alternatively, skidding may be required
  - Additional fabrication supports needed for fabrication of SBT and Hull at one site
  - If SBT and Hull are fabricated separately, additional arrangement is required to install SBT under the Hull.
- Offshore Installation :
  - Lowering SBT on mooring chains: Load equalization at each corner is provided and uneven load sharing between the groups is included;
  - Tendon installation : Installation risks (such as clashing) should be managed and weather window identified.
  - The system is storm safe at any installation step. Operations can be interrupted if necessary.

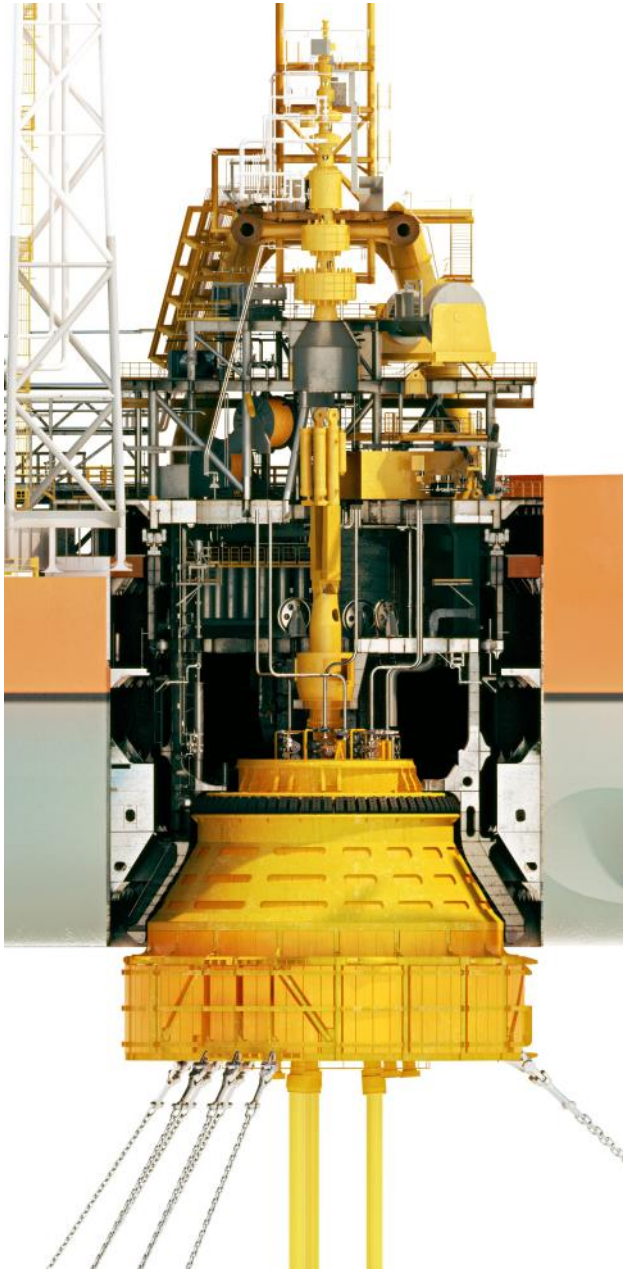
Technical and Economical Advantages

Main Technical Advantages

- ✓ Elimination of turret
- ✓ Use of SCRs + Simplified field layout
- ✓ Elimination of wellhead platform (if used)

Economical Advantages

- Extensive cost estimating performed for FPSO applications around the world
- More than 50% CAPEX savings could be achieved on hull, mooring and risers in the range of $500 – 1,000 Million

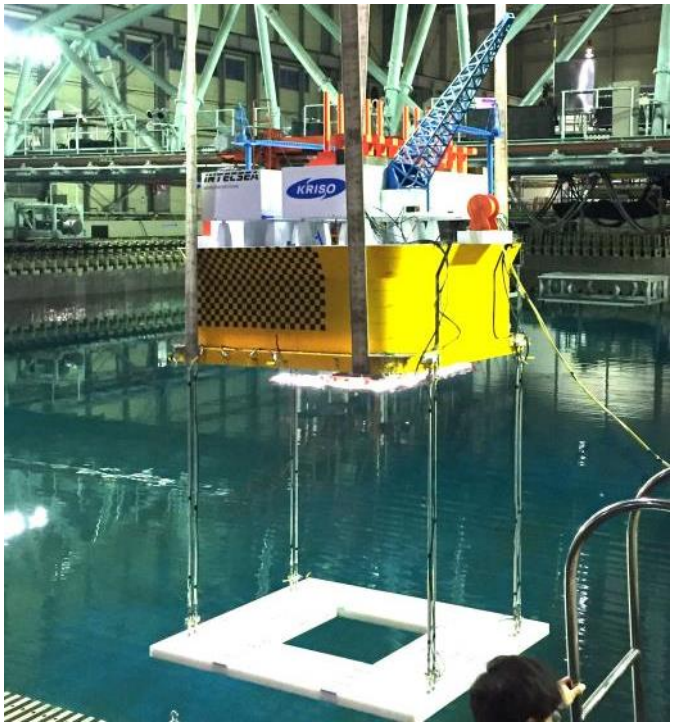


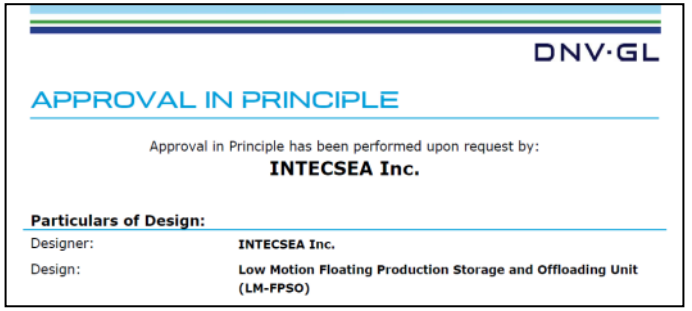
Application to FLNG

- LM-FLNG hull: L150m x B100m x D40m = Prelude displacement
- Because of high GM, can built the topside up vertically
- Advantages of LM-FLNG
  - Elimination of turret, one of the main sources of leaks
  - Use of large diameter SCRs even in relatively shallow water
  - Water intake riser can be supported at SBT level, ~ 200m below WL
  - Reduced sloshing in storage tanks, may open to prismatic B-tanks or possibly even membrane tanks
  - Improved operability of topside equipment and helicopter operations
  - Possibility of Side-by-side offloading (compared with round hull shape)
  - Protection of t^o - sensitive equipment (can be placed as high as required)
  - Improved Human Factors with better habitability

Technology Status

- ✓ Technical feasibility and economical advantage of the LMF has been studied and demonstrated
- ✓ Constructability review was completed by a major Korean shipyard. No issues identified
- ✓ Extensive model tests completed at KRISO in Nov. 2016 that confirmed the exceptional motion response
- ✓ Risk workshop with major oil companies was completed in Feb. 2017; no show stoppers identified
- ✓ Basic engineering package including a method of construction and installation was completed in Feb. 2017 and submitted to Class Society
- ✓ Base case project execution plan is ready; various alternative options are being studied
- ✓ E&P Special Meritorious Award for Engineering Innovation (at OTC 2017)
- ✓ Approval in Principle granted by DNV-GL
- ✓ **Technology is project ready**





DNV·GL

APPROVAL IN PRINCIPLE

Approval in Principle has been performed upon request by:
INTECSEA Inc.

Particulars of Design:

Designer:	**INTECSEA Inc.**
Design:	**Low Motion Floating Production Storage and Offloading Unit (LM-FPSO)**

Thank You!

INTECSEA

WorleyParsons Group

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