Deepwater Projects
DRL Engineering - Deepwater

- DRL Engineering Deepwater Expertise
  - Field Option Selection
  - Cost Estimating
  - Benchmarking
DRL Engineering Health Check and Front End Loading (FEL) Model

Health Checks can be done at any time, but analysis and recommendation will vary at different stages in this "Stage Gate" Process.

- **Health Check focuses on Concept Range and especially if Cost is in the "right Ballpark" and consistent between options.**
- **Health Check focuses more on scope and cost and FEED Target Setting.**
- **Health Check focuses on scope optimization and Realism of Sanction Cost and Schedule.**
- **Health Check on Execution Progress and focus on "Actions" to maintain cost and schedule.**
- **Health Check "Look Back" focuses on what went well and what could have been better. Important FEEDBACK and lessons learned.**

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**Stage Gate Process:**

- **FEL-1:** Appraisal Opportunity
- **FEL-2:** Develop Scope
- **FEL-3:** Define Project
- **Start Up and Operate:** Execute

**Key Phases:**

- **Appraise:** Developing the Business and basic feasibility
- **Select:** Translation of Prototype Project into a Business Case
- **Execute:** Advancing One Concept to the point where Detail Design can start
- **Project Execution**
EXPERIENCE – OFFSHORE PROJECTS

- Petronas Bokor Phase 3 EOR VE Study
- Murphy Kikeh DTU Spar – Options Studies for EOR Facility
- Owner Engineer assist on Falklands TLP development
- BC Petroleum ROC Oil – FPSO PMT Conversion Team at KSL Yard
- Talisman Kinabalu Redevelopment – Concept Select studies
- Talisman BK-D Platform VE Process & Facility Studies
- Newfield Blk 310 Sour Gas Platform FE Studies
- Twinza PNG FE Studies Pasca NGL Recycling & FSO Development
- EM of Petrofac FPSO Engineering for Aker in KL
- Start-up Operator - PSC Bid Functional Basis & Cost Estimate
- Husky Energy – Madura FPSO Owner Engr & ITT Tender Prep
- Talisman Kinabalu Platform Debottlenecking FE and Owner Engr
- Hess North Malay Basin Platform VE & FE Concept Design Studies
- Ophir RSC Peer Review and PM Support Services
- ALNG LNG Hub Concept Design
- KBB Project Close Out Report
- Newfield East Piatu Platform VE Process & Facility Studies
- MP225A Subsea Tie Back Host Modifications
- Petronas Baronia Platform VE Studies
- PM lead for Murphy Azurite FDPSO Decommissioning
- North Rankin B Project Close Out Benchmarking
- SK Energy B15 Concept Select to Pre-Feed Design Package
- CNOOC Liwan CPF Platform Cost Reduction Study
- Enquest Tj Baram RSC Ph 1 PM Services
Water Depth – Shallow, Deepwater & Ultra Deep

- Shallow Water to 300 meters
- Deepwater 300 meters to 1,500 meters
- Ultra Deep 1,500 to 3,000 meters

- Fixed Structure to 530 meters
- Compliant Towers 305 to 910 meters
- Tension Leg Platforms 150 to 1,600 meters
- Semi Submersibles 230 to 2,400 meters
- SPAR 600 to 2,400 meters
- FPSO 20 to 2,900 meters
- Subsea Tie Back to 3,000 meters
- Americas
  - GOM
  - Newfoundland
  - Brazil
  - French Guyana
- Africa
  - Nigeria
  - Angola
  - Ivory Coast
  - Equatorial Guinea
  - Egypt (Lebanon, Israel)
- Europe
  - Norway
  - West of Shetlands
  - Black Sea
- Asia
  - Brunei
  - Malaysia
  - NW Shelf Australia
  - East India
Deepwater

Brazil and the Gulf of Mexico Dominate the Deepwater Market
Deepwater Hull Forms

- **SPARS** (Single Lift and Multiple Lift)
- **TENSION LEG PLATFORMS** (Mini TLP’s and Conventional TLP’s)
- **SEMI SUBMERSIBLES**
- **FPSOs** (New Build and Conversions)
### Advantages:
- Permits drilling & completions operations (well interventions) onboard (DVA wells)
- Ultra deep (to 3000m+)

### Disadvantages:
- Shallow water depth restricted
- Little/no storage
- Installation costs & risks - requires heavy lift vessel
- Topsides payload sensitive
Advantages:

- Stable - minimal vertical motion
- Single drill center permits drilling & completions ops (including well interventions)
- Shallow to deep (120 to 1500m)
- Simpler well hardware + access
- Less flow assurance risk
- Topsides & hull mated inshore and transported to site

Disadvantages:

- Water depth limited (~1500m)
- Little/no storage – dead oil
- Topsides payload sensitive
# TENSION LEG PLATFORMS – Oveng / Okume

<table>
<thead>
<tr>
<th>Equipment Weight</th>
<th>Metric Tonnes</th>
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<tr>
<td>Total Topside Weight</td>
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<table>
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<tr>
<th>Bulk</th>
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<td>Piping / Electrical / Instrument</td>
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<tr>
<td>Secondary Steel</td>
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<table>
<thead>
<tr>
<th>Buildings &amp; Living Quarters</th>
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<tr>
<td>Utility Building</td>
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<tr>
<td>Workshop / Warehouse</td>
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<td>Control Room and LQ Building</td>
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<tr>
<td>Living Quarter Module</td>
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<td>Helideck</td>
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<tr>
<td>Total</td>
<td>151.2</td>
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SEMI SUBMERSIBLES – Advantages / Disadvantages

**Advantages:**
- Permits (limited) drilling & completions ops
- Shallow to ultra deep (150 to 3500m water depth)
- Support a large number of risers (payload)
- Topsides & hull mated inshore and transported to site for installation

**Disadvantages:**
- Little storage (Na Kika~40k bbls dead oil)
- Vertical motions limit DVA well access & riser performance
- Large mooring footprint
### PROJECT DATA

<table>
<thead>
<tr>
<th>Description</th>
<th>Delta House</th>
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<tr>
<td>Oil Production Capacity in Barrels/day</td>
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<tr>
<td>Gas Production Capacity in Million Cubic Feet/day</td>
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<tr>
<td>Design Throughput in BOG per Day</td>
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<tr>
<td>Water Injection Capacity in Barrels/day</td>
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<tr>
<td>Water Depth in meters</td>
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<tr>
<td>Hull Dry Weight in Tons</td>
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<tr>
<td>Substructure Installation Location</td>
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<tr>
<td>Pre-Image in Tons (Including Plus at 106 tonnes each)</td>
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<tr>
<td>number of mooring lines</td>
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<tr>
<td>Topside Weight excluding Rigs in Tons</td>
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<tr>
<td>Deck Weight in long</td>
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<td>Number of Production Wells</td>
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<td>Number of Water Injection Wells</td>
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<td>Number of Gas Injection Wells</td>
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<td>Export Line - Length and DE</td>
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<tr>
<td>Start Fabrication</td>
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<tr>
<td>First Hicommission</td>
<td>17 April 2014</td>
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<tr>
<td>First Fabrication to First Hydrocarbons</td>
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<tr>
<td>FID to first Hicommission in Months</td>
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</table>
Advantages:
- Ample buoyancy for large payloads
- Storage capacity (~3MM bbls)
- Shallow to ultra deep (100 to 3000m+ wd)
- Multiple mooring configurations
- No oil export pipeline required

Disadvantages:
- No drilling/completions ops (DVA) or interventions (to date)
- Limited advantage for gas fields
The giant Leviathan field (17 TCF)
2000 Mmscfd Gas Production FPSO

DRL PROJECT MANAGEMENT - LEVIATHAN FPSO

Our Personnel – lead roles in Owner PMT

Steve Craig, PM
Chris Lyttle
Hull Delivery Manager
Colby Hafner
Safety QRA
Vince Page
Rotating Machinery
### Basis of Design Document

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
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<tr>
<td>Leviathan BOD Subsea</td>
<td>EPS Subsea, Risers &amp; Export Pipelines</td>
<td>Subsea Equipment</td>
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<tr>
<td>Surface Facilities</td>
<td>EPS FPSO</td>
<td>Controls</td>
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<td>Steel Caisson Risers</td>
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<td></td>
<td>Export Pipeline &amp; INGL Tie-in (Israel)</td>
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<td></td>
<td></td>
<td>Export Pipeline (Cyprus)</td>
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<td>Transportation</td>
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<td></td>
<td>Installation</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Commissioning</td>
<td></td>
</tr>
</tbody>
</table>

### Organization

- Hull
- Otopsides
- Riser Pouch
- Suction Pipes
- Mooring (Chain, Synthetic, Chain)
- Transportation
- Installation
- Commissioning
- Condensate Offloading System

### Datasheet Index

<table>
<thead>
<tr>
<th>Sheet Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Sheet 1</td>
<td>Fieldwide Basis Design Data Book - Leviathan FPSO</td>
</tr>
<tr>
<td>Data Sheet 2</td>
<td>Leviathan Field Development</td>
</tr>
<tr>
<td>Data Sheet 3</td>
<td>Basis of Design Document</td>
</tr>
</tbody>
</table>

### Datasheets
LEVIATHAN FPSO

Spread Moored VLCC with SCR Riser System

2000 Mmscfd Gas Facility

28,000 MT Topsides
Leviathan FPSO Fabrication Scope of Work Overview

Hull Demolition Scope
1. Forward windlass x 1 unit
2. Anchor chain x 1 unit
3. Poop deck winch x 3 units
4. Main deck winch x 5 units
5. Hose handling crane x 2 units
6. Provision crane x 2 units
7. Bow thruster
8. Main deck piping & conduit
9. Main deck outfitting
10. Telecom & Navigation equip
11. LO equipment
12. Engine Room equipment
13. E&I items

Hull Piping Systems
1. Cargo Oil System
2. Ballast Water System
3. Inert Gas system
4. Compressed Air system
5. Steam/Feed/Cond. Water syst.
6. N2 system
7. MEG system
8. SW cooling syst (Marine & Topside)
9. FW cooling syst
10. Offspec produced water & cond. syst.
11. Open drain & closed drain system
12. FW distribution system
13. Fire syst
14. Fixed fire suppression syst
15. Hydraulic Oil sys
16. Fuel Gas system
17. MEG & Methanol syst
18. Foam System
19. Diesel Oil

Hull Coating & Painting
1. Hull painting – 500, 700m2
2. Main deck – 18, 000m2
3. N1 WBT – 229, 536m2
4. 11 COT – 155, 000m2
5. Slow tanks 15, 000 m2
6. Offspec tanks – 19, 000m2
7. FWT – 1, 000m2
8. APT – 8, 000m2
9. Chemical tanks – 25, 000m2
10. Ext Super Structure – 5, 170m2

Other Hull Misc Scope
1. 2 x FW generators & SW ejectors
2. Lifting Equip
3. Cargo offload & mooring equipment
4. Safety equipment
5. Ballast tank dehumidifier
6. New emergency generator
7. New sewage treatment plant
8. Tank anodes 4, 800 # x 50 kg
9. Hull anodes 600 # x 100 kg
10. Hatch covers
11. Tank air vents
12. Refurbish machinery equipment
13. COW machine
14. Heating coils in slop tank
15. OH valves
16. F&I navigation & communication equip

Dry-dock scope:
1. Riser porch
2. New Sea Chests
3. SW Lift pump caisson
4. Sacrificial anodes
5. Bilge Keel
6. Fairlead support str
7. Blast & Coating
8. MGPS system
9. Hull painting
10. Hull coating

Hull & Marine Scope +/- 10000 Tons

- Vessel details:
  - Built: 2012 by DSME Korea
  - Dim: L 333m x W 60m x D 30.5m
  - Deadweight: 320, 000 T
  - Class: ABS

- Workshop & storage (50 T)
- Marine Pipe rack (150 T)
- Convert 5S BT To FW tanks 1 & 2 (150T)
- Bilge Keel (250T)
- Riser Porch 1450T
- Fatigue Brackets (350 T)
- 130m Flare Tower (400 T)
- 2 x IO Towers (45 T)
- Fwd temp Shelter (60 T)
- Offloading Station (80 T)
- 4 x 6 mooring system (1500 T)

- Lifeboat Supports (250 T)
- Helideck (230T)
- New poop deck (450 T)
- Workshop & storage (50 T)
- Marine Pipe rack (150 T)
- Convert 5S BT To FW tanks 1 & 2 (150T)
- Bilge Keel (250T)
- Riser Porch 1450T
- Fatigue Brackets (350 T)
- 130m Flare Tower (400 T)
- 2 x IO Towers (45 T)
- Fwd temp Shelter (60 T)
- Offloading Station (80 T)
- 4 x 6 mooring system (1500 T)
KEY DRIVERS in Field Development

- Basin Strategy
- Reservoir Uncertainties
- Geohazards
- Metocean
- Field Architecture
- Flow Assurance
- Host Selection
- Technology & Risk
Our Concept Engineering Focus:

• Project Feasibility Assessment (Commercial and Technical);
  • Concept Identification & Selection:
    ➢ Export routes
    ➢ Process & Technology Options, Layout Studies;
    ➢ CAPEX / OPEX / Product Revenue Evaluation
  • Concept Optimisation:
    ➢ Engineering definition, Cost Sensitivities, Schedule
  • Debottlenecking Studies;
  • Risk Evaluation (Commercial and Technical);
  • Workshop Facilitation/Participation

We apply a stepwise ‘gate’ process to the Concept Select process to avoid recycle
• Reservoir Support Mechanisms (Primary & Secondary)
• Well Performance, Well Count & Location
• Well Fluid PVT & Physical Properties, WAT, Corrosion, Rheology, Chemistry
• Production System Capacities (Stream Day & Annual)
• Boundary Export Conditions (Pipelines / Injection / Terminal)
• Site Location & Environmental Data & Criteria
• Production Availability Requirements – Contract Obligations?
• Operations Philosophy, also EPC or Lease Operate?
• Future Facilities / Developments
• Specific Operator Preferences / Requirements – e.g. sparing, no. trains…
• Codes & Regulations selection
• Infrastructure Owned or Contractually Available
• Timing, Schedule Criticality, Opportunities & Risks
Examples of Typical Key Facility Parameters:

- Field Architecture Options – Vertical vs Extended reach Drilling, Cluster versus daisy Chain DCs, Initial versus Future etc..
- Hull Options – DTU vs Wet Trees, Riser Stability, Payload, Cost, Quayside or Offshore Installation
- Export Options – Pipeline, FPSOs, FSOs.
- Flow Assurance Options – Displacement vs Insulated vs Chemical Reclaimer.
- Topsides Riser Pressure Break, Trains & Configuration
- Process Unit Robustness to achieve dead oil and on spec gas
- Equipment Type Selections – Drivers, Unit Ops. etc..
- Utility Options for Power, Cooling and Heating
- Packaging / Layout, Safety, Payload

Optimum Cost with consideration of Weight, Feasibility Risk & Schedule
DEFINE THE BUILDING BLOCKS

- Building Block
  Export Pipeline System
- Building Block
  Drilling
  Surface Drilling Rig System
- Building Block
  Topside Facilities
- Building Block
  Hull and Mooring
- Building Block
  SCR Import Risers System
- Building Block
  Flowlines
- Building Block
  Flowlines/Pipelines Flowline System
- Building Block
  Well Systems
  Drilling and Completion by MODU
- Building Block
  Reservoir
- Building Block
  Tie-in Subsea System
We led the Front – End Studies and Option Selection for 3 Fields
TYPICAL DEVELOPMENT ISSUES

- Field Architecture configuration and impact on drill rig locations and drill centers – i.e. daisy chain, cluster or DVA

- Hull Type – drilling location, DTU vs Wet Trees, drilling reach, riser performance and loads, oil storage and integration (quayside lift, strand jacks or offshore lift or floatover)

- Well Back Pressure - justify artificial lift- ESPs, gaslift riser, riser pumping, MPPs Cost / Feasibility vs Deliverability & FA.

- Export Options – Pipelines, FSO / FPSO / FLNG terminals

- Flow Assurance – well offset distance, rheology, displacement vs insulation vs Chemical and Reclaiming

- Integration & Installation Options – Lift, Floatover, Quayside or singlebuild with strand jacks or nearshore floatover

- Riser dia vs SIP vs type (SCR vs Flexible), Riser Loads, Riser install, Riser & Connector Fatigue & Type, TOR spec break

- Topside Equip Selections & Systems (e.g. direct drives, HM/CM..)

- Layout optimization – incl. HSE & HMI & Maintenance etc.

- Fabrication location – total actual cost implications
### Costs (Mill USD)

- Host: 347
- Hull: 150
- Mooring, risers: 109
- Subsea equipment: 166
- Pipelines, FL, umbilicals: 129

**Total:** 901

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**Generating Options**

- FPSO
- MODU
- FPSO tanker
- Gas re-injection
- Water injection
- Benita

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**Overall Rating**

<table>
<thead>
<tr>
<th>Concept &amp; Robustness</th>
<th>Weighting %</th>
<th>BOPF</th>
<th>Host Type</th>
<th>Processing Location</th>
<th>Storage &amp; Loading</th>
<th>MGL Storage &amp; Loading</th>
<th>Gas Delivery</th>
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<td>Transport/Installation – Hook Up</td>
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**Weighted Total:** 100

**Notes:**

- Gas compression efficiaent connection with FPSO may result in high installation difficulties, see dry trees, 2 not trees accessed via a MODU. Flaring not allowed.
- Score high on BOPF because no high pressure fluids, and all flowlines are tied into a fixed structure. The jacket needs to be totally welded and there is no chance for separate NGL products which has a penalty on high scores.
- The jacket requires more effort of installation compared to flowlines.
- Score high on NGL because there is no separate NGL product with which to deal.
- Score low on gas disposal as all the gas is respected, no need for pipelines.
Examples of typical options
## EXAMPLE – HULL SCREENING OPTIONS

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<thead>
<tr>
<th>Concept</th>
<th>Mature Technology</th>
<th>Field Effective Capacity</th>
<th>Safety</th>
<th>Sea Ice Impact</th>
<th>Flexibility</th>
<th>Relocation</th>
<th>Execution Model</th>
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<td>6</td>
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<td>Mini TLP</td>
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<td>SEMI Hub Only</td>
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<td>Buoy</td>
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<td>10</td>
<td>10</td>
<td>8</td>
<td>61</td>
<td>1</td>
</tr>
</tbody>
</table>
We are specialized in bringing discoveries to fruition through a methodical and systematic Conceptual Engineering process.

Our methodology and experience includes brownfield as well as greenfield, de-bottle necking and increased oil recovery projects.
Concepts are identified, screened and defined – function, scope, cost and schedule are established.
## EXAMPLE PRE-SANCTION WORK PLAN

### PROJECT INFO:

**XX Development**

<table>
<thead>
<tr>
<th>PROJECT INFO</th>
<th>2012</th>
<th>2013</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>JAN</td>
<td>FEB</td>
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<tr>
<td>DEVELOPMENT MILESTONES</td>
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<tr>
<td>Charter</td>
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<tr>
<td>Functional Basis (SOR)</td>
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<td>4</td>
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<tr>
<td>Contracting Strategy</td>
<td>5</td>
<td>6</td>
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<tr>
<td>Contractor Tendering &amp; Evaluation</td>
<td>7</td>
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<tr>
<td>Regulatory Framework &amp; Plan</td>
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<td>Plan of Development (POD)</td>
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<td>Risk Assessment</td>
<td>13</td>
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<tr>
<td>Budget &amp; Cost Estimates</td>
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<td>O&amp;M Strategy &amp; Operability</td>
<td>17</td>
<td>18</td>
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<tr>
<td>PEP</td>
<td>19</td>
<td>20</td>
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<tr>
<td>Peer &amp; Partner Reviews</td>
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### SUBSURFACE

<table>
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<tr>
<th>DRILLING</th>
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<th>2013</th>
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<tbody>
<tr>
<td>A-2 Appraisal Well</td>
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<tr>
<td>A-3 Appraisal Well</td>
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### SURFACE FACILITIES

<table>
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<tr>
<th>SURFACE FACILITIES</th>
<th>2012</th>
<th>2013</th>
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<tbody>
<tr>
<td>Process and Facilities Studies - Offshore</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Process and Facilities Studies - Onshore</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Hull Selection Studies</td>
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<td>6</td>
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<tr>
<td>Preliminary BOD</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Option Selection Studies</td>
<td>9</td>
<td>10</td>
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<tr>
<td>FEED Definition - Offshore</td>
<td>11</td>
<td>12</td>
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<tr>
<td>FEED Definition - Onshore</td>
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<td>14</td>
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### SUBSEA

<table>
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<tr>
<th>SUBSEA</th>
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<th>2013</th>
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<tbody>
<tr>
<td>Metocean Study</td>
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<td>2</td>
</tr>
<tr>
<td>Flow Assurance studies</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Field Architecture Studies</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Flowline &amp; Export Line Engineering</td>
<td>7</td>
<td>8</td>
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<tr>
<td>Preliminary Cost, Schedule &amp; FEED</td>
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<td>10</td>
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<tr>
<td>Multi Beam &amp; AUV Surveys</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Riser Study</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>FEED</td>
<td>15</td>
<td>16</td>
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<tr>
<td>Contractor &amp; Market Assessments</td>
<td>17</td>
<td>18</td>
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Track Record of Floating Concept Selection
Floating Concept Selection

- **KME (March 2014)**
  - Subsea Tie Back to KBB
  - Tension Leg Platform with Wet Trees and Partial Processing
  - Tension Leg Platform with Wet Trees and Full Processing

- **Kekek (January 2014)**
  - Mini Tension Leg Platform
  - Single Lift SPAR
  - Multiple Lift SPAR
  - Semi Submersible

- **Leviathan Gas FPSO (Jan 14-17)**
- **Sea Lion (November 2013)**
  - TLP / FPSO

DRL specializes in bringing discoveries to fruition through a methodical and systematic Conceptual Engineering process.
Floating Concept Selection

- Mad Dog 2 (November 2013)
  - All Floating Concepts

- Abadi Floating vs. Onshore LNG (February 2013)
  - Semi Submersible
  - FPSO

- Limbayong (February 2012)
  - New Deepwater Hub
  - Shallow Water Platform with Subsea Tie Back
  - Subsea Tie Back to KN

- Malikai (2007-2011)
  - All Floating Concepts
• Floating Concept Selection

— Gumusut (2003-2007)
  • All Floating Concepts

— Perdido (2004-2005)
  • Multi Lift SPAR vs. Single Lift SPAR

— Equatorial Guinea Basin
  Noble Energy Benita FPSO
  & Elon Condensate Recycle

- CMS Energy ALBA

- Chevron JSM Hull Type
DEEPWATER PROJECT
COST ESTIMATING & BENCHMARKING
Offshore Project - Cost Estimating Overview

COST ESTIMATING

Deep Water Estimating

Subsea & Pipelines

Shallow Water Estimating

Brownfield Estimating
Deepwater Project – Work Breakdown Structure Level 1

Development Cost

Facility Cost

Drilling and Completion

Project Management & Client

- Substructure and Moorings
  - Project Leadership
  - Site Team
  - Procurement
  - Fabrication

- Topside
  - Design
  - Site Team
  - Procurement
  - Fabrication
  - Integration
  - Warm Up
  - Commissioning

Host

- Marine Installation
  - Trees
  - Manifolds
  - Controls
  - Umbilicals

- Subsea Facilities
  - Subsea Hardware
    - Design
    - Procurement
    - Fabrication
    - Inspections
    - Surveys
    - Installation

- Export Lines
  - Flowlines
    - Design
    - Procurement
    - Fabrication
    - Inspections
    - Surveys
    - Installation
DEEPWATER PROJECTS: WHERE DO WE SPEND OUR CAPEX?

Non Direct Vertical Access Projects

Direct Vertical Access Projects
### Cost Estimating – Cost Norm Format

**Offshore Development Facility Cost Norm Format: Progression of Detail Over Time**

<table>
<thead>
<tr>
<th>Work Breakdown Structure</th>
<th>Level One</th>
<th>Level Two</th>
<th>Level Three</th>
<th>Level Four</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical % of Facility Cost</td>
<td>During Identify and Access</td>
<td>During System Selection</td>
<td>During Define</td>
<td>During Execution</td>
</tr>
<tr>
<td>Project Leadership</td>
<td>% of Facility Cost</td>
<td>% of Facility Cost</td>
<td>Cost Time Resource Organization Chart Durations</td>
<td>Cost Time Resource Organization Chart Durations</td>
</tr>
<tr>
<td>Client and Insurance</td>
<td>% of Facility Cost</td>
<td>% of Facility Cost</td>
<td>Manpower Rates</td>
<td>Manpower Rates</td>
</tr>
<tr>
<td>Hull</td>
<td>Cost Per Tonne</td>
<td>Cost per Tonne</td>
<td>Cost Time Resource Organization Chart Durations</td>
<td>Cost Time Resource Organization Chart Durations</td>
</tr>
<tr>
<td>Moorings</td>
<td>Cost per Meter</td>
<td>Cost per Meter</td>
<td>Manpower Rates</td>
<td>Manpower Rates</td>
</tr>
<tr>
<td>Topside</td>
<td></td>
<td></td>
<td>Insurance Tender</td>
<td>Insurance Bid</td>
</tr>
<tr>
<td>Marine Installation</td>
<td>Cost Per Tonne</td>
<td></td>
<td>Design Manhours</td>
<td></td>
</tr>
<tr>
<td>Subsea</td>
<td>Cost per Tree</td>
<td>Cost per Tree</td>
<td>Cost Time Resource Design Bid</td>
<td></td>
</tr>
<tr>
<td>Control Cost per Well</td>
<td>Cost per Tree</td>
<td>Cost per Tree</td>
<td>Cost Time Resource Manpower Rates</td>
<td></td>
</tr>
<tr>
<td>Umbilical Cost per Mile</td>
<td>Cost per Sled</td>
<td>Cost per Sled</td>
<td>Procurement Rates</td>
<td></td>
</tr>
<tr>
<td>Flowlines</td>
<td>Cost per Inch Dia Mile</td>
<td>Cost per Inch Dia Mile</td>
<td>Fabrication Bid</td>
<td></td>
</tr>
<tr>
<td>Export Lines</td>
<td>Cost per Inch Dia Mile</td>
<td>Cost per Inch Dia Mile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schedule</td>
<td>Schedule Assumed via Cost Norms</td>
<td>Schedule Assumed via Cost Norms</td>
<td>Detailed Project Specific Schedule</td>
<td>Detailed Project Specific Schedule</td>
</tr>
</tbody>
</table>

**Norm Change with Progression of Information**
Cost Estimating – Greenfield Structure

LEVEL ONE / TWO OFFSHORE SCOPE and COST ESTIMATING BUILDING BLOCKS

INPUT REQUIREMENTS Oil
Throughput, Gas Throughput,
Water Injection Throughput,
Number of Beds, Water Depth,
Design Premise, Sulphate
Reduction, Type of Rig and
CONCEPT and Fabrication
Location

INPUT REQUIREMENT Number of
Wells, Number of Manifold Slots,
and umbilical Miles

INPUT REQUIREMENT Diameter
and installed Miles, bare or
insulated Pipe

INPUT REQUIREMENT Diameter
and installed Miles, bare or
insulated Pipe

INPUT REQUIREMENT Modular or
Stick Build Offshore, weight by
discipline

Facility Cost

Host Scope and Cost

Topsides

Topside Payload

Hull Weight

Mooring / Tendon

Marine Installation

Subsea

Flowlines

Export Lines

Brownfield Scope

PROJECT LEADERSHIP

CLIENT AND INSURANCE

INPUT REQUIREMENT Shell or
EPIC Contract and Geographical
Region
# Deepwater Cost Estimating – Input Data Requirements

## Data Input – Pre FEED Deliverables

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Throughput</td>
<td>60,000 BOPD</td>
</tr>
<tr>
<td>Gas Compression Throughput &amp; Suction &amp; Discharge Pressures</td>
<td>100 MMscfd</td>
</tr>
<tr>
<td>Pipeline/Cargo/OMB Pumps Discharge Pressure</td>
<td>100 MMscfd</td>
</tr>
<tr>
<td>Water Injection Throughput &amp; Discharge Pressure</td>
<td>0 BWPD</td>
</tr>
<tr>
<td>Number of Beds in Living Quarters (Ops, Maint, Constr - exclude rig)</td>
<td>30</td>
</tr>
<tr>
<td>Number of Beds in Living Quarters (Calculated Total - includes rig)</td>
<td>160</td>
</tr>
<tr>
<td>Number of Beds per Room in Living Quarters (2 or 4)</td>
<td>4</td>
</tr>
<tr>
<td>ILP &amp; Spar Well Type (DVA or Subsea or DVA + Subsea)</td>
<td>DVA + Subsea</td>
</tr>
<tr>
<td>Water Depth</td>
<td>1000 Meters</td>
</tr>
<tr>
<td>Semi &amp; FPSO Wells</td>
<td>Subsea</td>
</tr>
<tr>
<td>Procurement/Ref Location (GOM, Far East, Europe (excl. Norway), Norway, Singapore or Malaysia)</td>
<td>GOM</td>
</tr>
<tr>
<td>Number of Mooring Lines</td>
<td>12</td>
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<tr>
<td>If FPSO Hull Storage Capacity in barrels</td>
<td>12</td>
</tr>
<tr>
<td>If FPSO Does FPSO have a Turret (Yes or No)</td>
<td>No</td>
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<tr>
<td>If FPSO Does the FPSO require Offshore Loading Buoy (Yes or No)</td>
<td>No</td>
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<tr>
<td>If FPSO IS FPSO Hull to be New Build (Yes or No)</td>
<td>No</td>
</tr>
<tr>
<td>If FPSO IS FPSO Hull to be a Conversion (Yes or No)</td>
<td>No</td>
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<tr>
<td>If SPAR or TLP</td>
<td>Number of Direct Vertical Access Risers</td>
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<td>Number of Drilling Risers</td>
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<tr>
<td>Design Premise (Contractor or Shell)</td>
<td>Shell</td>
</tr>
<tr>
<td>Drilling Rig Type (None or Workover or Tender or Full)</td>
<td>Full</td>
</tr>
<tr>
<td>Is Drilling Rig Capex (Yes or No)</td>
<td>No</td>
</tr>
<tr>
<td>Is Water Depth of Host &lt; 400m (Yes or No)</td>
<td>Yes</td>
</tr>
<tr>
<td>Gulf of Mexico Projects (Yes or No)</td>
<td>Yes</td>
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<tr>
<td>Number of Subsea Wells</td>
<td>12</td>
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<tr>
<td>Number of Manifold Slots</td>
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<tr>
<td>Number of Stacks</td>
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<tr>
<td>Umbilical Length in Miles</td>
<td>15</td>
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<tr>
<td>Flowline Installation Length in miles</td>
<td>15</td>
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<tr>
<td>Flowline Diameter in inches</td>
<td>8</td>
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<tr>
<td>Flowline Diameter in dia miles</td>
<td>120</td>
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<tr>
<td>Export Line Installation Length in miles</td>
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<tr>
<td>Export Line Diameter in inches</td>
<td>20</td>
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<tr>
<td>Export Line Diameter in dia miles</td>
<td>1,500</td>
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</tbody>
</table>
Deepwater Cost Estimating

Standard Work Breakdown Structure

- Topsides
  - Design
  - Equipment Procurement
  - Bulk Procurement
  - Living Quarters
  - Offshore Building
  - Erection Site Team
  - Fabrication
  - Load or Hook Up
  - Commissioning
  - Topsides Estimate
  - Embellishments
  - Umbilicals
  - Subsea Estimate
  - $6,562,500 per mile

- Drilling Rig
  - Trees
  - Manifolds
  - Risers
  - Controls
  - $9,462,500 per well

- Subsea
  - Umbilicals
  - Subsea Estimate
  - $3,018,750 per well

- Well Systems
  - DVA Risers
  - Flowlines
  - Drilling Risers
  - Well System Estimate
  - $66,100

- Flowlines / Export Lines
  - Flowline Estimate
  - $49,000
  - Export Line Estimate
  - $66,100

- 10% Contingency
  - 10% topsides cost
  - 90% topsides cost
  - 80% contingency 30%
  - Most Likely topsides cost
  - 90% topsides cost

- Conventional TLP
  - $96,346,587
  - $77,463,964
  - $84,243,402
  - $89,194,976

- SPAR Single Lift
  - $79,018,477
  - $80,541,277
  - $80,541,277
  - $80,541,277

- SPAR Multiple Lift
  - $73,843,187
  - $84,211,836
  - $221,054,477
  - $220,054,477

- Semi Submersible
  - $80,412,400
  - $80,541,277
  - $80,541,277
  - $80,541,277

- FPSO Single Level Modules
  - $247,290,000
  - $247,290,000
  - $247,290,000
  - $247,290,000

- FPSO Mix of Single and Multi-Level Modules
  - $247,290,000
  - $247,290,000
  - $247,290,000
  - $247,290,000

- FPSO Mostly Multi-Level Modules
  - $247,290,000
  - $247,290,000
  - $247,290,000
  - $247,290,000

- Arctic Gravity Based Structures
  - $247,290,000
  - $247,290,000
  - $247,290,000
  - $247,290,000
Regional Fabrication Costs

Topside Fabrication Cost Per Tonne By Region (Final Cost)
US$50 Oil Market

Costs include:
- Cost of Labour
- Payroll Burden & Living Costs
- Preliminaries
- Shop Drawing Costs
- Fabrication Supervision
- Subcontracts
- Construction Engineering
- Consumables
- Construction Equipment
- Fees (Profit)

<table>
<thead>
<tr>
<th>Region</th>
<th>Fabrication Cost per Tonne in US$</th>
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<tbody>
<tr>
<td>China</td>
<td>$5,041</td>
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<tr>
<td>Thailand</td>
<td>$5,568</td>
</tr>
<tr>
<td>Indonesia</td>
<td>$7,563</td>
</tr>
<tr>
<td>Mexico</td>
<td>$8,000</td>
</tr>
<tr>
<td>Singapore</td>
<td>$8,809</td>
</tr>
<tr>
<td>Malaysia</td>
<td>$9,445</td>
</tr>
<tr>
<td>Brunei</td>
<td>$9,632</td>
</tr>
<tr>
<td>Gulf of Mexico</td>
<td>$11,790</td>
</tr>
<tr>
<td>Philippines</td>
<td>$11,849</td>
</tr>
<tr>
<td>Korea</td>
<td>$11,922</td>
</tr>
<tr>
<td>Italy</td>
<td>$12,235</td>
</tr>
<tr>
<td>Spain</td>
<td>$12,513</td>
</tr>
<tr>
<td>Netherlands</td>
<td>$13,458</td>
</tr>
<tr>
<td>Caspian</td>
<td>$13,625</td>
</tr>
<tr>
<td>UAE</td>
<td>$14,091</td>
</tr>
<tr>
<td>Norway</td>
<td>$15,571</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>$15,571</td>
</tr>
<tr>
<td>Australia</td>
<td>$16,272</td>
</tr>
<tr>
<td>China</td>
<td>$18,686</td>
</tr>
</tbody>
</table>
Fabrication of Modules in China
DRL cost estimates are established based on data of actual achieved costs on previous projects.

Scope

- Production Capacity
  - 9,600 barrels/day Oil/Condensate (exported via spike into Gas Line)
  - 800 mmscfd Gas (Input Pressure 700psi Export 1,500 psi)
- Water Depth 760m
- Hull Dry Weight 10,662 tonnes
- Topside Dry Weight 10,593 tonnes
- Total Installed Power 36 MW
- Living Quarters 50
- 8 Tendons
- Drilling via Tender Assist
- Wellbay 6 slots
- Cost Estimate to include 3 Top Tension Risers
- Gas Export Line Carbon Steel 22" 80 miles to new Riser Platform
DRL cost estimates are established based on data of actual achieved costs on previous projects.
DRL Project Benchmarking Database

• DRL Project Benchmarking Database
  – Data from 287 Projects used to perform
    • Concept Benchmarking
    • Scope Benchmarking
      – Value Engineering
      – Risks and Opportunity Assessments
    • Cost Benchmarking
    • Schedule Benchmarking
    • Project Health Checks

DRL ENGINEERING BENCHMARK DATASET
287 Projects
180 Process Facilities
33 Subsea Tie Back
74 Wellhead Platforms
Project Database (excl. Subsea Tie Backs and Wellhead Platforms)

180 Process Facilities
of which
122 Projects are Deepwater Projects
In Addition
DRL Benchmark Database includes 74 Wellhead Platforms
BENCHMARKING OVERVIEW

CONCEPT

SCHEDULE

Benchmarking

SCOPE

COST
• Scope Benchmarking Metrics

• Cost Benchmarking Metrics

• Schedule Benchmarking Metrics
SCOPE BENCHMARKING

- Scope Benchmarking Checks will vary Project to Project but will include:
  - Design Functionality vs. Reservoir Size
  - Total Installed Power vs. Design Functionality
  - Total Installed Power vs. Topside Dry Weight
  - Functionality vs. Topside Weight
  - Topside Dry Weight vs. Deck Area
  - Deck Area vs. Functionality
  - Living Quarter Weight vs. Number of Beds
  - Equipment Weight vs. System Functionality
    - Production
    - Compression
    - Power
    - Water Injection
    - Utilities
    - Safety and Material Handling
  - Jacket Weight vs. Water Depth
  - Hull Weight vs. Topside Weight
  - Link Bridge vs. Bridge Length
Topside Weight vs. Daily BOE (All Hull Forms)
SPAR DEVELOPMENTS
Topside Dry Weight excl. Rig vs. Daily Design Throughput in BOE
Tension Leg Platform Topside Weight vs. Daily BOE

TENSION LEG PLATFORM DEVELOPMENTS
Topside Dry Weight excl. Rig vs. Daily Design Throughput in BOE

- Mars B (Post Katrina)
- Hutton (1st Generation)
- Auger (1st Generation)
- URSA
- Papa Terra Wellhead TLP
- Kizomba A Wellhead TLP
- Conventional Tension Leg Platform
- Mini Tension Leg Platform
- Malikai
- Brutus
- MARS A
- Ram Powell
- Stampede
- Shenzi
- Magnolia
- Marlin
- Typhoon
- Prince
- Oveng
- Marco Polo

Topside Dry Weight in Tonnes vs. Daily Design Throughput in BOE
Semi Submersible Topside Weight vs. Daily BOE
NEW BUILD FPSO Topside Weight vs. Daily BOE

- NEW BUILD FPSO DEVELOPMENTS
- Topside Dry Weight excl. Rig vs. Daily Design Throughput in BOE

Key Points:
- Multiple Deck FPSO
- Single Deck FPSO
- Various FPSO names and capacities are plotted on the graph.

Graph Details:
- Y-axis: Topside Dry Weight in Tonnes
- X-axis: Daily Design Throughput in BOE
- Various FPSO names like Pazflor, Egina, Abami, Angola 18, etc., are plotted on the graph.

Graph Notes:
- The graph helps in understanding the relationship between the weight of FPSO topsides and their daily design throughput.
OFFSHORE BEST WEIGHT PERFORMERS

INCORPORATE BEST PRACTICES WHERE APPLICABLE

HORN MOUNTAIN SPAR

INDEPENDENCE HUB SEMI SUBMERSIBLE

MARCO POLO MINI TLP

NEPTUNE SPAR

MARS A CONVENTIONAL TLP

SHENZI MINI TLP
• Cost Benchmarking Checks will vary Project to Project but will include:-

  – Hull Cost per Tonne
  – Topside Cost per Tonne
  – Topside Design Manhours per Tonne
  – Equipment Procurement Cost per Tonne
  – Topside Bulk Procurement Cost per Tonne
  – Fabrication Cost per Tonne
  – Hook Up and Commissioning Cost per Tonne
  – Topside Installation Cost vs. Topside Weight
  – Mooring Cost vs. Installed Length
  – Pipeline Line Cost per Inch Dia. Mile
  – Subsea Costs (Trees/Manifolds/Controls/Umbilicals/IWOC/Jumpers)
DRL – Deepwater Cost Benchmarking

• Deepwater Project Benchmarking Packages
  – Including Scope, Cost & Schedule Benchmarking

  – Malikai Tension Leg Platform Malaysia 2016
  – Stones Conversion FPSO Gulf of Mexico 2016
  – Leviathan Gas FPSO & current CPF Platform 2017
  – Knarr New Build FPSO Norway 2015
  – Delta House Semi Submersible Gulf of Mexico 2015
  – Sea Lion Conversion FPSO Falkland Islands 2015
  – Mars B Tension Leg Platform Gulf of Mexico 2014
  – Gumusut/Kakap Semi Submersible Malaysia 2014
  – Mad Dog 2 Semi Submersible Gulf of Mexico 2014
  – Skarv New Build FPSO Norway 2012
Deepwater Project Benchmarking Packages
- Including Scope, Cost & Schedule Benchmarking
  - Gjoa Semi Submersible Norway 2011
  - Who Dat Semi Submersible Gulf of Mexico 2011
  - Perdido Single Lift SPAR Gulf of Mexico 2010
  - BC 10 Conversion FPSO Brazil 2007
  - Independence Hub Semi Submersible Gulf of Mexico 2007
  - Mag Dog SPAR Gulf of Mexico 2005
  - Na Kika Semi Submersible Gulf of Mexico 2003
  - Penguin Subsea Tie Back North Sea 2003
  - EA New Build FPSO Nigeria 2002
Schedule Benchmarking Checks will vary project to project but will include:

- Critical Path Duration to First Cut Steel
- Fabrication Duration
  - Floating Hulls
  - Topsides
- Final Investment Decision to Sailaway
- Final Investment Decision to First Hydrocarbons
Gulf of Mexico Semi Submersible Project Summary Schedule

<table>
<thead>
<tr>
<th>Activity</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
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<td>Jan</td>
<td>Feb</td>
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<td>Front End Engineering</td>
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<td>Detail Design</td>
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<td>Topside Long Lead Material Procurement</td>
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<td>Procure Subsea Trees</td>
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<td>Procure Line Pipe</td>
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<td>Bid &amp; Award Hull &amp; Topsides</td>
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<td>Fabrication</td>
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<td>Drill &amp; Complete Wells</td>
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<td>Transport Host to Gulf of Mexico</td>
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<td>Hook Up &amp; Install Flowlines/Imbibicals</td>
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<td>First Hydrocarbons</td>
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<td>Detail Design to First Hydrocarbons</td>
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<td>First Fabrication to First Hydrocarbons</td>
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</table>
• Typical Deepwater Benchmarking Package: Scope (Charts 3 to 19), Cost (Charts 20 to 33) and Schedule Review (Charts 34 to 36) and Benchmarking Summary (Charts 37 to 39)
State-of-the-art services go beyond traditional benchmarking and peer-assisted investment decision-making to provide a comprehensive suite of services.

**Training**
- Data Collection
- Benchmarking Metrics
- Project Concepts
- Cost Efficiency
- Estimating Tools

**Cost Estimating**
- Estimating Tools:
  - Scope Development
  - Cost Development
  - (Deep Water, Shallow Water, Brownfield & Subsea)
  - Regional Norms

**Schedule Benchmarking**
- Execution Duration vs Capacity

**Scope Benchmarking**
- Spar Developments
  - Topside Weight vs Capacity

**Cost Benchmarking**
- Host Cost vs Capacity

**Peer Assists & Investment Decision**
- Providing Global Advice:
  - Scope
  - Execution Strategy
  - Cost and Schedule
  - Identify Opportunities & Risks

More than Benchmarking...
DRL Engineering - Deepwater

• DRL Engineering Deepwater Expertise
  • Option Selection
  • Cost Estimating
  • Benchmarking