Ultra-Deepwater Appraisal Production System (APS)

Converted 6th Gen MODU with 15k Dry Tree Tiebacks – 5 Wells ➔ 40-60 MBOPD

4,000-8,000ft WD        40,000ft Drilling

Providing:
• All Existing Technology Components
• Increased Safety
• Improved Decision Quality
• Improved Well Operations
• Improved Reserves Recovery

with
• Greatly Reduced Costs and Risks

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The Commercial Environment for Ultra-DW
Lower Tertiary E&P is in a Critical State

- Much greater reservoir uncertainty
  - Subsalt/Poor reservoir seismic quality
  - Thick pay intervals with multiple zones
  - Expensive and few appraisal wells
  - Little production/completion history
    - Faulting and connectivity unknown
    - Reservoir drive mechanisms unknown
    - Sand control & completion uncertainty
    - Intervention frequency unknown
- Very high development drilling costs
  - 35,000’ wells requiring >250 days
  - Many require new 20K MODU (BOP, drilling riser and intervention system) with 20K back up
- Subsea development with 20k equipment and HIPPS imposes long term large CAPEX and OPEX

➔ Lack of reservoir and completion performance information means huge, riskier bets
Holding onto a discovery is costly

BOEMR rule allows operators of discoveries 180 days between well operations for a lease continued beyond its primary term

• Appraisal Well takes 200 days to drill and evaluate
  ➔ ~1 well per year to hold lease
• Wells have cost over $200MM

Shenandoah case study -

  7 Year total at least $1.4B sunk
  ➔ Well log information and coring data only
• No production or completion data
• Reserves recovery per well unknown
• DSTs are very costly and do not provide adequate reservoir risk reduction

Industry needs a commercially viable Appraisal Production System

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Appraisal Production System (APS) Enables Dramatic, Cost Effective Risk Reduction

• Convert 6th Gen Semi-Submersible to Appraisal Production System (APS) with Dry or Wet Trees
  • APS will meet ABS, BSEE and USCG requirements
  • Direct Vertical Access for Drilling, Completion, and Well Intervention Increases Reservoir Productivity and Reserve Recovery
  • Ability to use 15K direct hydraulic surface equipment and fully rated risers eliminates the need for 20K subsea technology

• Accelerated first oil date & earlier positive cash flow –
  • 40Mbopd production is viable at $50 per bbl
  • Delivered at ½ the cost and ½ the schedule

• Gain valuable reservoir and completion data to better define the overall field development requirements while making MONEY

➡ Real Risk Reduction
  • Ability to right-size the field development scheme OR
  • Enables “least cost to condemn” approach

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**APS Core Concept**

**Increase Safety/Decrease Costs**

- Remove subsea BOP, drilling riser, DP system and all associated hardware
- Install **movable wellbay** that supports dry tree well tieback risers with a polyester taut leg mooring system
  - Allows wellheads to be located beneath the center of the drilling derrick for drilling and completion operations
  - Supports 5 top tension dual barrier risers
  - Safety of Moored Platform, Fully Rated High Pressure Risers and reliable Surface BOP

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Moveable Moonpool Wellbay Assembly –
Structural Well Systems Interface to APS

- Cart holds 5 tensioner sets and is designed to slide laterally
- Cart locked in place during well operations or hurricane abandonment
- Cart provides structural support for tension ring in extreme events
- Tree remains inside hull at maximum downstroke.
Wireline Tensioner Plan View

14' 500 Kips 500 Kips 500 Kips 500 Kips 500 Kips
12'
# 6th Gen MODU Conversion Payload Impact

## Remove

<table>
<thead>
<tr>
<th>MODU Equipment</th>
<th>Payload Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Drilling Riser and Tensioner</td>
<td>Frees up 4,200 tons</td>
</tr>
<tr>
<td>Drilling Riser Top Tension Allocation</td>
<td>Frees up 2,000 tons</td>
</tr>
<tr>
<td>Subsea BOPE and Test Stump</td>
<td>Frees up 600 tons</td>
</tr>
<tr>
<td>Subsea BOP/Tree Cart and Handling Equip</td>
<td>Frees up 200 tons</td>
</tr>
<tr>
<td>Marine Drilling Riser Racking Equipment and Storage Area</td>
<td>Frees up 200 tons</td>
</tr>
<tr>
<td>DP Thrusters and Power Generation</td>
<td>Frees up 400 tons</td>
</tr>
</tbody>
</table>

### TOTAL REDUCTION

Over 7,500 tons

## Add

<table>
<thead>
<tr>
<th>15K Dry Tree Equipment</th>
<th>Payload Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface BOPE</td>
<td>Add 200 tons of payload</td>
</tr>
<tr>
<td>5-Well Moonpool Tensioner Cart</td>
<td>TBD</td>
</tr>
<tr>
<td>5 Dual Barrier Q-125 TTR’s with Distributed Buoyancy</td>
<td>(~750 \text{kips per riser} \rightarrow \text{1,900 tons})</td>
</tr>
<tr>
<td>40-60M BOPD Production Facilities</td>
<td>Add 1,200 tons (Ref. Horn Mountain topsides)</td>
</tr>
<tr>
<td>Taut Leg Polyester Mooring System</td>
<td>TBD.. mostly below waterline</td>
</tr>
<tr>
<td>Export Oil and Gas Riser Interfaces</td>
<td>Lazy Wave or SLOR Export Risers</td>
</tr>
</tbody>
</table>
Movable Wellbay in Moonpool

System to survive 1,000 year Hurricane in Central Gulf of Mexico
Initial studies have established **Feasibility**

- Candidate Semisub List and Contract Status Compiled
  - Representative MODU selected for feasibility study
- Dual Barrier Riser Design adopted based on qualified HS Tubulars (Vallourec)
- 12 point Polyester Taut-leg Mooring Analysis for 100 and 1,000 year hurricane (Orcaflex)
- Dual Barrier Riser Stroke and Strength Analysis for 100 and 1,000 year hurricane (Orcaflex)
- Moveable Wellbay Tensioning Cart Sizing and Configuration (Ansys and Solidworks)
- 40KBPD Facilities Equipment List, Size, Weight and Cost based on previous work
  - Sized initial prefabricated module

➢ ABS Approval in Principle awarded with “road map” to Class Approval
  ➢ HAZID workshop completed in February
Riser Design and Analysis

- **Dual Barrier Riser Design adopted based on qualified HS Tubulars (Vallourec)**

- **12 point Polyester Mooring Analysis for 100 and 1,000 year hurricane (Orcaflex)**

<table>
<thead>
<tr>
<th>Outer Riser</th>
<th>Inner Riser</th>
<th>Tubing</th>
</tr>
</thead>
<tbody>
<tr>
<td>OD</td>
<td>14.75 in</td>
<td>11.75 in</td>
</tr>
<tr>
<td>Wall Thickness</td>
<td>1 in</td>
<td>1 in</td>
</tr>
<tr>
<td>ID</td>
<td>12.75 in</td>
<td>9.75 in</td>
</tr>
<tr>
<td>Cross Sectional Area</td>
<td>43.2 in²</td>
<td>33.6 in²</td>
</tr>
<tr>
<td>Weight per Foot</td>
<td>147.0 lbs/ft</td>
<td>117.3 lbs/ft</td>
</tr>
<tr>
<td>Material</td>
<td>Q-125</td>
<td>Q-125</td>
</tr>
</tbody>
</table>

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Riser Stroke for GoM Winter Storms

Tensioner System Design Downstroke

<table>
<thead>
<tr>
<th>Storm Return Interval</th>
<th>Winter Hs Downstroke</th>
<th>Winter HMax Total Stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.1</td>
<td>7.4</td>
</tr>
<tr>
<td>10</td>
<td>5.2</td>
<td>9.4</td>
</tr>
<tr>
<td>100</td>
<td>6.8</td>
<td>12.3</td>
</tr>
</tbody>
</table>

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Riser Analysis – Managing Stroke & Stretch

- Dual Barrier Riser Stroke and Strength Analysis for 100 and 1,000 year hurricane (Orcaflex)

Pressure-driven riser design

- 10ft of stretch increases stress by 50ksi in 6,000ft WD
- The riser can be stretched 25ft before reaching yield
Investigating Airgap in Extreme Events

100 Year GoM Hurricane Max Wave Height

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Coupled APS Riser Analysis – Stretch and Slack

RISER STROKE AND VESSEL POSITION
1000 Year Hurricane, Total Stroke 40 ft (Upstroke 10 ft)
125 ksi Riser, 800 kips Nominal Tension

- Wave/Wind - Max Vessel Position
- Storm Surge (Downstroke)
- Current (Downstroke)
- Offset (Downstroke)
- Wave/Wind - Min Vessel Position
- Tensioner Mean Position

TWO risers connected
Coupled analysis shows that the risers restrict heave responses so that stress only reaches \(<\frac{2}{3} \text{ YS}\) in 1000yr event max waves.
APS and the Operators’ Alternatives

- **APS with Dry Trees** – *works at $50/bbl*
  - Can add remote subsea tree tiebacks
- **APS with DVA and Remote Wet Trees**
- **Spar with Dry Trees**
  - As large or larger than Holstein to support 2.5 million lb. derrick
- **Spar/Semi with 20K Wet Trees**
  - Subsea wells allows possibility for wider spread of penetrations into the reservoir – Cost prohibitive at today’s oil prices
- **FPS (converted semi MODU) with 20K Wet Trees**
- **FPSO with 20K Wet Trees**

- **Sell or farm down the discovery**
- **Release the asset**

Over 70 candidate rigs available world-wide
Paleogene Reservoir Input

- Paleogene production is in its infancy
- Discounting production from the Perdido area (where the oil and rock quality are much better), then production is available from the following fields
  - Cascade & Chinook
  - Jack & St Malo
  - Julia

APS with 5 wells

- 40kbopd
- 30kbopd
P50 Cashflow: APS vs FPS thru 5 wells ($50/bbl)

**Dry Tree Wells**
- 100 days to Complete & Tie Back ➔ +$50M ea

**Subsea Wells**
- 120 days to Complete & Tie Back ➔ +$180M ea

- **ALL WELLS**
  - 190 days Pre-Drilling w/ Subsea BOP

- **$50 Flat Oil Price**
- $6/bbl Operating Cost Dry Tree
- $10/bbl Operating Cost Wet Tree
- Avg Well Initial Production 10,000 bbl/day
P50 Cashflow at $75/bbl: APS vs. Semi-Sub

- APS installed CAPEX ~$1bn
- Semi-Sub 10 SS Wells
- FPS installed CAPEX ~$1.9bn
- APS 5 Dry Tree Wells
- Sanction
- First Oil

2016 Decision Frameworks, L.P. Evaluation for Frontier Deepwater Appraisal Solutions
Comparison of Economic Performance

### $50/BBL

<table>
<thead>
<tr>
<th>15mbopd Paleogene Production Profile</th>
<th>SOP (10 wet trees)</th>
<th>APS (5 dry trees)</th>
<th>APS (8 wet trees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV</td>
<td>(2,491)</td>
<td>437</td>
<td>703</td>
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<tr>
<td>PI</td>
<td>-0.052</td>
<td>1.36</td>
<td>1.444</td>
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<tr>
<td>Disc CapEx</td>
<td>2,367</td>
<td>1,213</td>
<td>1,584</td>
</tr>
<tr>
<td>Cum Oil</td>
<td>320</td>
<td>174</td>
<td>272</td>
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</tbody>
</table>

### $75/BBL

<table>
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<th>APS (8 wet trees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV</td>
<td>(2,283)</td>
<td>1,435</td>
<td>2,062</td>
</tr>
<tr>
<td>PI</td>
<td>0.036</td>
<td>2.184</td>
<td>2.302</td>
</tr>
<tr>
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<td>2,367</td>
<td>1,213</td>
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"SOP" – 20K Subsea with 80kbopd FPS (Spar)
Semi-Sub 10 SS Wells vs. APS 5 Dry Tree Wells
$75/bbl Oil Price – Range of Value Comparison

**Semi-Sub 10 SS Wells**
- EV = (2,116 MM$)
- P10 = (2,260 MM$)
- P50 = (2,097 MM$)
- P90 = (1,999 MM$)
- Value < 0 = 100%

**APS 5 Dry Tree Wells**
- EV = 291 MM$
- P10 = (647 MM$)
- P50 = 164 MM$
- P90 = 1,398 MM$
- Value < 0 = 34%
VOI Decision Tree shows real value of Phased APS Dry Well Concept ($75/bbl Oil Price)

Semi-Sub 10 well,
ENPV = $2,117 MM$

APS 5 Dry Tree Wells,
ENPV = $291 MM$

Phased APS 10 Wells,
ENPV = $533 MM$

2016 Decision Frameworks, L.P. Evaluation for Frontier Deepwater Appraisal
Movable Wellbay with Subsea Trees and Direct Vertical Access

For APS with Subsea Trees and Direct Vertical Access:
- Production top tension risers – dual tube can handle 2 wells
- Workover risers to be used on subsea trees
- Full 19” ID 15K drilling riser to be used on subsea trees

APS with Mudline Separation (Perdido Config)
- Caissons are located under APS and risers tied back to moveable wellbay

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Study Objectives

- Mature the technology
  - Confirm feasibility findings
  - Advance AIP/NTQ with ABS
- Better Define Semisub requirements and availability
- Update Rig Market (Pricing) and Rank Candidates
- Improve Cost & Schedule Estimates
- Plan FEED program
  - Be prepared to secure MODU