OPERATIONS

Defining Expanded Sectors for DP-Assisted Offloading Operations in Spread-Moored Platforms

Eduardo Tannuri

Petrobras
Defining Expanded Sectors for DP Assisted Offloading Operations in Spread Moored Platforms

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Douglas G. T. Yuba

Gilberto B. Machado
Cap. José Luiz P. Malafaia
Petrobras, Brazil

October 2016
1) Introduction
2) Objective
3) Methodology
4) Preliminary Risk Assessment
5) Downtime Analysis
6) Real Time simulations
7) Field Tests
8) Conclusion
Introduction

Exploration activities in Brazil

• FPSO platforms are important players
  • 30 units in operation (against 16 semi-submersibles)
  • 20 more to be installed until 2020

• Pre-salt fields
  • Ultra deep Waters (~ 2,500 m)
  • Remote locations (~ 300 km from the coast)
  • Harsh environmental conditions

• DP assisted offloading
  • DP-1 and DP-2 shuttle tankers
  • Special attention due to FPSO fixed heading
    • Sudden weather changes may be a threat to safety
Introduction

Difficulty for keeping position aligned to the FPSO
Introduction

Campos Basin
- Wind: 7.7 m/s ; 193°
- Surface Current: 0.36 m/s ; 193°
- Swell: Hs = 1.41 m, Tp = 10.1 s, Peak Direction = 141°
- Local-Sea: Hs = 1.57 m, Tp = 6.32 s, Peak Direction = 73°

Santos Basin
- Wind: 7.7 m/s ; 72°
- Surface Current: 0.26 m/s ; 235°
- Swell: Hs = 1.5 m, Tp = 9.8 s, Peak Direction = 141°
- Local-Sea: Hs = 1.64 m, Tp = 6.47 s, Peak Direction = 96.7°

Difficulty for keeping position aligned to the FPSO
Even worse for the new pre-salt oil fields
Introduction

• Operating sectors
  • Green, yellow and red zones to increase safety and avoid collisions
  • Some operations are still interrupted affecting offloading uptime
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Main objectives

- Evaluate the possibility of extending the operating sector from 60° to 75°~90° (starboard)
- Establish a meticulous but sufficient methodology to evaluate it
- Calculate offloading operations downtime
- Evaluate offloading operations risks
Objective

“Normal” Operation
Shuttle Tanker aligned to the FPSO

Operation in the expanded sector

Questions
1) What is the additional risk?
2) Is the dowtime decreased?
1) Introduction
2) Objective
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5) Downtime Analysis
6) Real Time simulations
7) Field Tests
8) Conclusion
Methodology

Preliminary Risk Analysis → Downtime Static Analysis → Fast Time Dynamic Simulations → Real Time Simulations

Validation in full scale operations
Agenda

1) Introduction
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8) Conclusion
Methodology

- Qualitative risk assessment
- Petrobras norm for industrial risk analysis
- Group of specialists:
  - two DPST Captains
  - four naval engineers
  - two risk analysis consultants
  - one TPN-USP specialist

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Preliminary Risk Assessment sheet

Name:                                                                 Date:       Rev.:
Conclusions

• The analysis identified that the operational sector must be smaller than 90° to avoid interference between hull structures and the hawser.

• Additional risks:
  • Risk of engine room flooding → detailed stability analysis
  • Risk escape manoeuvre
Conclusions

- If a drive-off takes place the tanker could hit the platform’s stern and damage the hull causing flooding in the engine room. In this case, the FPSO structural integrity could be endangered.

-Stability Software SSTAB was used to simulate damage on the engine room in several units of the fleet. The analysis showed that this risk is actually very low.
Conclusions

- Most part of the simulations showed no need of concern. In some specific loading conditions and in some specific platforms, though, the maximum bending moments or shear forces may come close or slightly exceed the envelope of admissible values.

- An adequate contingency plan that takes into account this possibility of engine room flooding and if it provides procedures of cargo or ballast transfer to avoid endangering the hull integrity, this risk can be considered moderate.
Conclusions

• New proposed sector
  • Hatched green sector: under low thrusters demand only

The maximum angle was defined as $75^\circ$ to $80^\circ$ after the PRA.
Agenda

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Downtime Static Analysis

Premises

- Shuttle tanker: DP Class 2

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<td>Displacement (ton)</td>
<td>170,000</td>
<td>80,000</td>
</tr>
</tbody>
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Suezmax DP 6600kW +Main Propeller

Houston, TX, USA | October | 2016
MTS DP Conference
Downtime Static Analysis

Methodology

• Static analysis

• Input:
  • Hindcast data: 17,537 environmental conditions every 3h
  • Hull’s coefficients
  • Thrusters capacities (80% nominal power – IMCA dynamic margin)
  • Operating sector limits
  • Acceptance criteria

• Output:
  • Environmental loads on DPST
  • Thrust allocation, if stationkeeping is possible
  • Seasonal downtime
Acceptance criteria

• Hs < 3.5m (contractual criterion)

• Wind speed < 40 knots (contractual criterion)

• Fx<22 kN (equivalent to a wind of 10 knots and waves of 1m Hs) – No stern forces...

• The thrust on the most demanded propeller must be less than 80% (dynamic margin of 20% as suggested by IMCA, 2000)

• Shuttle’s roll amplitude is less than 6° (to guarantee comfort on board of the ST, according to Capitains’ experience)

• The criteria 1 to 6 must be valid for the environmental conditions during the 36h operation time
Downtime Static Analysis

Results (increasing green sector from 60° to 75°)

<table>
<thead>
<tr>
<th>Basin</th>
<th>Uptime - Offloading Station</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Bow [%]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Original</td>
<td>Extended</td>
<td>Original</td>
<td>Extended</td>
</tr>
<tr>
<td>Santos</td>
<td>54.9</td>
<td>65.5</td>
<td>53.4</td>
<td>66.6</td>
</tr>
<tr>
<td>Campos</td>
<td>73.4</td>
<td>82.5</td>
<td>35.6</td>
<td>44.2</td>
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- Increasing the uptime of each individual station is beneficial enough
  - if the weather changes during an offloading, the DPST may not need to disconnect from one station and re-connect to the other

+9.8%  +11.8%  +3.5%
Downtime Static Analysis
Agenda

1) Introduction
2) Objective
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6) **Real Time simulations**
7) Field Tests
8) Conclusion
Real Time Simulations

TPN-USP Simulation Center

Facilities & team
- TPN Offshore real time simulator;
- 3-day simulation campaign
- 12 offloading operations simulated
- Team: Three experienced Captains, four naval engineers and three TPN specialists
Real Time Simulations

TPN-USP Simulation Center

Kongsberg K-POS DP System

DARPS (Virtual)

Technical Chart (Virtual)
### Real Time Simulations

#### Caso Navio Carreg. Aliviador Corrente Vento Mar Swell

<p>| | | | | | |</p>
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<td>1</td>
<td>Stavanger</td>
<td>Lastro (T=9m)</td>
<td>W (266°)</td>
<td>0.74nó</td>
<td>21 nós</td>
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<td>2</td>
<td>Stavanger</td>
<td>Lastro (T=9m)</td>
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<td>3</td>
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<td>Full (T=16m)</td>
<td>S (202°)</td>
<td>0.74nó</td>
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<td>Stavanger</td>
<td>Full (T=16m)</td>
<td>S (202°)</td>
<td>0.74nó</td>
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<tr>
<td>5</td>
<td>Stavanger</td>
<td>Full (T=16m)</td>
<td>SW (241°)</td>
<td>1 nós</td>
<td>10 nós</td>
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<tr>
<td>6</td>
<td>Stavanger</td>
<td>Full (T=16m)</td>
<td>SW (241°)</td>
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<tr>
<td>7</td>
<td>Stavanger</td>
<td>Interm. (T=11m)</td>
<td>S (190°)</td>
<td>1.2nó</td>
<td>20 nós</td>
</tr>
<tr>
<td>8</td>
<td>Stavanger</td>
<td>Interm. (T=11m)</td>
<td>S (190°)</td>
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<td>9</td>
<td>Stavanger</td>
<td>Interm. (T=11m)</td>
<td>S (190°)</td>
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<tr>
<td>10</td>
<td>Stavanger</td>
<td>Interm. (T=11m)</td>
<td>W (270°)</td>
<td>1.2nó</td>
<td>20 nós</td>
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<tr>
<td>11</td>
<td>Stavanger</td>
<td>Interm. (T=11m)</td>
<td>W (270°)</td>
<td>1.2nó</td>
<td>20 nós</td>
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<tr>
<td>12</td>
<td>Stavanger</td>
<td>Full (T=16m)</td>
<td>W (270°)</td>
<td>1.5nó</td>
<td>20 nós</td>
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- Different loading conditions
- Approach and connection
- Heading change to reduce DP power
- Drive-off
Real Time Simulations

Simulation 7:
- Cold Front condition
- Campos Basin

FPSO 210° Heading
Campos Basin

Current=1.2knot
190°

Wave
Hs=3.4m
Tp=10s
135°

Wind 20knots
135°
Real Time Simulations

Phase 1 – DPST aligned with the FPSO

High DP Thrusters demand

Large Roll Angle (~8°)

Wind+Wave
Real Time Simulations

- FPSO 210° Heading
- Campos Basin
- Current = 1.2 knots
- Wind = 20 knots
- Wave Hs = 3 m, Tp = 10 s
- 135°
- Basin
- Current = 1.2 knots
- 135°
- 135°
- 135°
- 135°

Houston, TX, USA | October | 2016

MTS DP Conference
Real Time Simulations

Phase 2 – DPST in the limit of actual sector

Reduced DP Thrusters demand

Reduced Roll Angle (~2°)

Wind+Wave
Real Time Simulations

FPSO 210° Heading
Campos Basin

Current=1.2 knots
190°

Wave
Hs=3.4m
Tp=10s
135°

Wind 20 knots
135°
Real Time Simulations

Phase 3 – DPST in the extended sector

Reduced DP Thrusters demand

Wind+Wave

Reduced Roll Angle (~1º)
Real Time Simulations

FPSO 210º Heading
Campos Basin

Current=1.2 knots
135º

Wind 20 knots

Wave Hs=3 m
Tp=10 s
135º

Vx = 0.3 km
Head.Aiv = 98 deg
DP.Consum.%(t)= 23.7%

Real Time Simulations

FPSO 210º Heading
Campos Basin

Current=1.2 knots
135º

Wind 20 knots

Wave Hs=3 m
Tp=10 s
135º

Vx = 0.3 km
Head.Aiv = 98 deg
DP.Consum.%(t)= 23.7%
Real Time Simulations

Heading 038 – Phase 1

Heading 090 – Phase 2

Heading 105 – Phase 3

FPSO 210º Heading
Campos Basin

Current=1.2 knots
180º

Wind 20 knots
135º

Wave
Hs=3.4 m
T=10 s
135º

Houston, TX, USA | October | 2016

MTS DP Conference
Simulation 7:
-Cold Front condition
-Santos Basin

FPSO 190° Heading
Santos Basin

Current = 0.74 knot 266°

Wind = 21 knot 103°

Wave Hs = 3m Tp = 7.6 s 113°
Actual Sector

Extended Sector

Real Time Simulations
Real Time Simulations

Vento = 21 nós 103º
Corrente = 0.74 nós 266º
Onda = 3 m Tp=7.6 s 113º

FPSO 190º Heading
Santos Basin

Current = 0.74 knot 266º
Wind = 21 knot 103º
Wave Hs= 3 m Tp=7.6 s 113º
Real Time Simulations

Drive-Off Simulations

Escape Maneuver – Thrusters and Propeller+rudder must be used to guarantee a safe distance with the FPSO
Real Time Simulations

Drive-Off Simulations
Real Time Simulations

Drive-Off Simulations

Thrusters + Propeller/Rudder

Only Propeller/Rudder
Real Time Simulations

It is recommended to keep the bow of the DPST away from the FPSO
Preliminary Conclusions

- Drive-off escape manoeuvres → successful
- Thrusters power demand → lower for extended sector
Agenda

1) Introduction
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Fiels Tests

• The new offloading sector was programmed in the DP software of a real shuttle tanker.

• Weather conditions were mild but it was possible to verify the automatic transition to bow-rotation, that occurred just fine. It was possible to notice that thrusters’ demand decreased, as expected.

• The updated DP console software will be adopted for the actual and new tankers.

• Recent feedback from Kongsberg and DPST Captains show that the new sectors and operation modes are being well accepted.
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Conclusions

Methodology
• Meticulous but enough to give confidence for field testing

Operating sector
• Initial proposal of 90° is discarded by now
• Sector may be extended to 75°
• Uptime gain – annual average
  • Santos Basin: 10.6% (bow); 13.2% (stern) (more than \textbf{37 days/year})
  • Campos Basin: 9.1% (bow); 8.6% (stern) (more than \textbf{31 days/year})
Thank you

eduat@usp.br

Eduardo A. Tannuri
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- FPSO: 205°
- DP Tanker

Difficulty for keeping position aligned to the FPSO

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- Wind: 7.7m/s; 72°
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Even worse for the new pre-salt oil fields
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**Objective**

**Main objectives**

- Evaluate the possibility of **extending the operating sector from 60° to 75°~90° (starboard)**
- Establish a meticulous but sufficient methodology to evaluate it
- Calculate offloading operations downtime
- Evaluate offloading operations risks

![Diagram of actual and proposed offloading sectors](image)
Objective

“Normal” Operation
Shuttle Tanker aligned to the FPSO

Operation in the expanded sector

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Methodology

- Preliminary Risk Analysis
- Downtime Static Analysis
- Fast Time Dynamic Simulations
- Real Time Simulations

Validation in full scale operations
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  • Risk of engine room flooding → detailed stability analysis
  
  • Risk escape manoeuvre
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- If a drive-off takes place the tanker could hit the platform’s stern and damage the hull causing flooding in the engine room. In this case, the FPSO structural integrity could be endangered.

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Premises

- Shuttle tanker: DP Class 2

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Downtime Static Analysis

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• Static analysis

• Input:
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  • Hull’s coefficients
  • Thrusters capacities *(80% nominal power – IMCA dynamic margin)*
  • Operating sector limits
  • Acceptance criteria

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Downtime Static Analysis

Results (increasing green sector from 60° to 75°)

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- Increasing the uptime of each individual station is beneficial enough
- if the weather changes during an offloading, the DPST may not need to disconnect from one station and re-connect to the other
Downtime Static Analysis
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Real Time Simulations

TPN-USP Simulation Center

Kongsberg K-POS DP System

DARPS (Virtual)

Technical Chart (Virtual)
**Real Time Simulations**

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<thead>
<tr>
<th>Caso</th>
<th>Navio</th>
<th>Carreg. Aliviador</th>
<th>Corrente</th>
<th>Vento</th>
<th>Mar</th>
<th>Swell</th>
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<td>SSE (103°)</td>
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<td></td>
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<td>Full (T=16m)</td>
<td>SW (241°)</td>
<td>1 nó</td>
<td>10 nós</td>
<td>S (181°)</td>
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<td>Stavanger</td>
<td>Interm. (T=11m)</td>
<td>S (190°)</td>
<td>1.2nó</td>
<td>20 nós</td>
<td>SE (135°)</td>
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<td>Interm. (T=11m)</td>
<td>S (190°)</td>
<td>1.2nó</td>
<td>20 nós</td>
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<td>9</td>
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<td>Interm. (T=11m)</td>
<td>S (190°)</td>
<td>1.2nó</td>
<td>20 nós</td>
<td>NE (45°)</td>
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<td>10</td>
<td>Stavanger</td>
<td>Interm. (T=11m)</td>
<td>W (270°)</td>
<td>1.2nó</td>
<td>20 nós</td>
<td>SE (135°)</td>
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<td>11</td>
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<td>Interm. (T=11m)</td>
<td>W (270°)</td>
<td>1.2nó</td>
<td>20 nós</td>
<td>SE (135°)</td>
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<td>Full (T=16m)</td>
<td>W (270°)</td>
<td>1.5nó</td>
<td>20 nós</td>
<td>NE (45°)</td>
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<td>NE (45°)</td>
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</table>

- Different loading conditions
- Approach and connection
- Heading change to reduce DP power
- Drive-off
Simulation 7:
-Cold Front condition
-Campos Basin
Real Time Simulations

Phase 1 – DPST aligned with the FPSO

High DP Thrusters demand

Large Roll Angle (~8°)

Wind+Wave
Real Time Simulations

- FPSO 210° Heading
- Campos Basin
- Current = 1.2 knots
- Wind = 20 knots
- Wave Hs = 3.4m
- Tp = 10s
- Heading Accuracy = 38°
- DP Consumption (%): 8%

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Real Time Simulations

Phase 2 – DPST in the limit of actual sector

Reduced DP Thrusters demand

Reduced Roll Angle (~2º)

Wind+Wave

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Real Time Simulations

FPSO 210° Heading
Campos Basin

Current=1.2 knots
135°

Wave Hs=3.4m
Tp=10s
135°

Wind 20 knots
135°
Real Time Simulations

Phase 3 – DPST in the extended sector

Reduced DP Thrusters demand

Wind+Wave

Reduced Roll Angle (~1°)
Real Time Simulations

- FPSO 210º Heading
- Campos Basin
- Current = 1.2 knots
- Wind = 20 knots
- Wave Height = 3 m
- Period = 10 s
- 135º
- Hs = 3.4 m
- Tp = 10 s
- 135º
- DP Consum. (%) = 23.7
Real Time Simulations

Heading 038 – Phase 1

Heading 090 – Phase 2

Heading 105 – Phase 3

FPSO 210º Heading
 Campos Basin

Current 1.2 knot 190º

Wave Hs=3.4m
Tp=10s 135º

Wind 20knots 135º

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Real Time Simulations

Simulation 7:
-Cold Front condition
-Santos Basin

FPSO 190° Heading
Santos Basin

Current = 0.74 knot 266°
Wind = 21 knot 103°

Wave Hs = 3 m Tp = 7.6 s 113°
Real Time Simulations

Actual Sector

Extended Sector
Real Time Simulations

FPSO 190° Heading
Santos Basin

Current = 0.74knot 266°
Wind = 21knot 103°
Wave Hs= 3m Tp=7.6 s 113°

Vento = 21 nos 103°
Corrente = 0.74 nos 266°
Onda = 3m Tp=7.6 s 113°

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MTS DP Conference
Real Time Simulations

Drive-Off Simulations

Escape Maneuver – Thrusters and Propeller+rudder must be used to guarantee a safe distance with the FPSO
Real Time Simulations

Drive-Off Simulations
Real Time Simulations

Drive-Off Simulations

Thrusters + Propeller/Rudder

Only Propeller/Rudder
It is recommended to keep the bow of the DPST away from the FPSO.
Real Time Simulations

Preliminary Conclusions

• Drive-off escape manoeuvres → successful
• Thrusters power demand → lower for extended sector

Drive-off simulation
Agenda

1) Introduction
2) Objective
3) Methodology
4) Preliminary Risk Assessment
5) Downtime Analysis
6) Real Time simulations
7) Field Tests
8) Conclusion
Fiels Tests

- The new offloading sector was programmed in the DP software of a real shuttle tanker.

- Weather conditions were mild but it was possible to verify the automatic transition to bow-rotation, that occurred just fine. It was possible to notice that thrusters’ demand decreased, as expected.

- The updated DP console software will be adopted for the actual and new tankers.

- Recent feedback from Kongsberg and DPST Captains show that the new sectors and operation modes are being well accepted.
1) Introduction
2) Objective
3) Methodology
4) Preliminary Risk Assessment
5) Downtime Analysis
6) Real Time simulations
7) Field Tests
8) Conclusion
Conclusions

Methodology
• Meticulous but enough to give confidence for field testing

Operating sector
• Initial proposal of 90° is discarded by now
• Sector may be extended to 75°
• Uptime gain – annual average
  • Santos Basin: 10.6% (bow) ; 13.2% (stern) (more than \textit{37 days/year})
  • Campos Basin: 9.1% (bow) ; 8.6% (stern) (more than \textit{31 days/year})
Thank you

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