OPERATIONS

DP Assisted Offloading Operations in Brazilian Waters

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The University of São Paulo

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DP Assisted Offloading Operations in Brazilian Waters

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BR PETROBRAS

Tanque de Provas Numérico

Summary

- Several aspects of DP assisted offloading operations in Brazilian Waters.

- Objective: to define a more accurate set of premises to the design of the DP System of the new Shuttle Tankers (ST) that will operate in Brazilian waters and to expose the actions that Brazilian scientific and industry communities are taking to define those premises.

Topics

- Introduction
- Petrobras Operational Guideline
- Full Scale Measurements
- Comparison DP x non-DP offloading
- Model Scale Tests
- Hydro/Aerodynamic Interaction FPSO/ST
- Conclusions
- Acknowledgments

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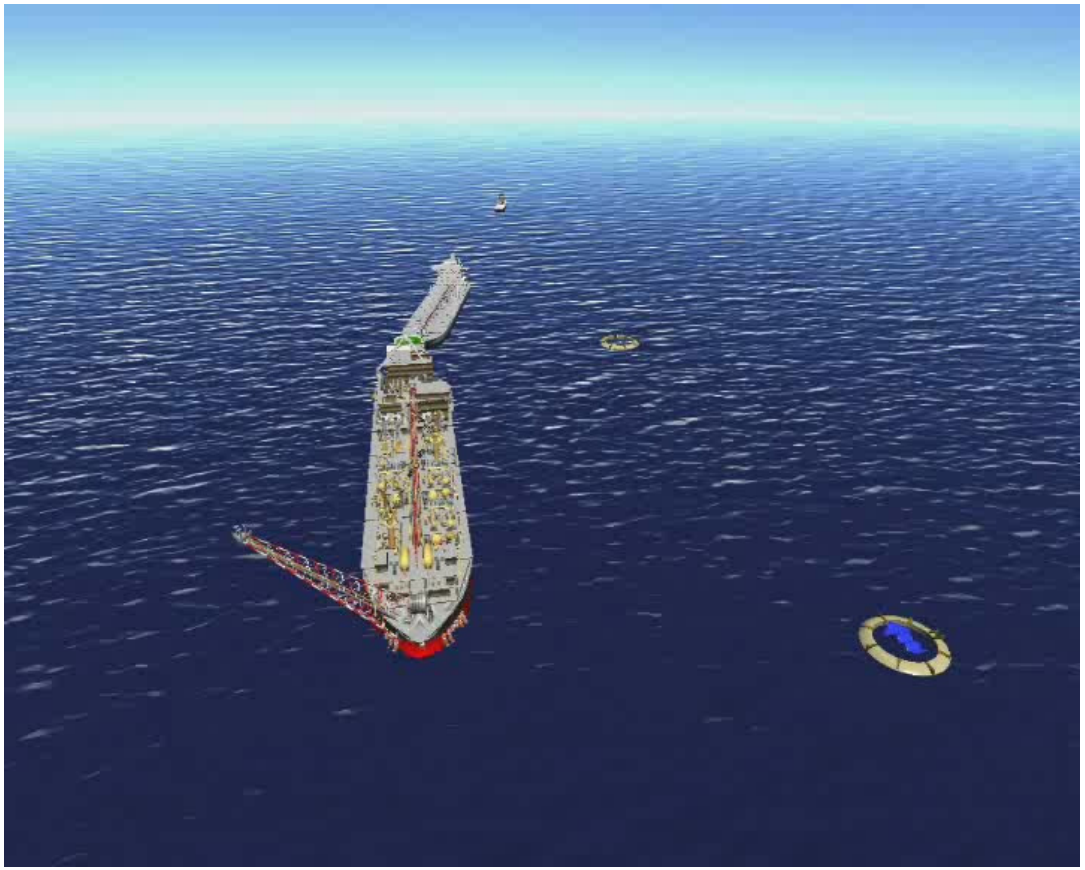
Significant changes in Brazil over the last years

Period	Offshore Terminal Type
70's - 80's	1 FSO and CALM Buoys
90's	CALM Buoys, FSOs and the 1st SPM-Turret
1998-2009	DP-FPSO (Seillean), SPMs Turret (14 units) Spread Moored (09 units)
From 2009	more FPSOs are expected (Spread Moored)

FPSO-based exploitation expansion ⇨ More Shuttles

Introduction

Conventional offloading NO - DP



Introduction

DP offloading

Introduction

DP offloading

Introduction

Today

- Interval among loadings: 5 days
- More than 600 off takings per year
- 12 DPSTs: 9 from TRANSPETRO, 3 hired abroad

Comparison DP x Non-DP ST

- Risk analysis recommended DP tankers to reduce the risk of collision (Spread Moored FPSO)
- 35% total operational time reduction
- Time for mooring and hose connection phases decreased
- Possible operations during the night

Near Future

- New Spread Mooring FPSO's
- Higher demand for more DP tankers

Renewing Fleet Program

Until 2002

- Conventional Trading Tankers

From 2002

- Trading Tankers (gradually replaced)
- 04 DP Class-1
- 08 Enhanced DP Class-1
- 01 DP Class-2
- 04 more vessels on 2009-2010
- More vessels are expected

Petrobras specification

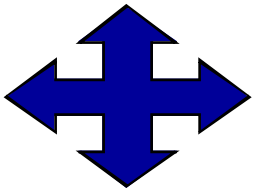
- 1994 - ST initial specification (BLS requirement)
- 1999 - ST with maneuvering assistance (thrusters) – no DP
- 2002 – DP Class 1 Enhanced
- 2006 – Additional thruster (8MW)
- 2009 – Additional thruster (10.6MW)

Introduction

- Constantly evolution scenario
- Cooperative programs with Brazilian scientific community
- Experimental and numerical studies to support important decisions about regulation and operational requirements for the offloading

Experimental Facilities

Numerical Simulators



Design Methodologies

Advanced Hidro/Aerodynamics

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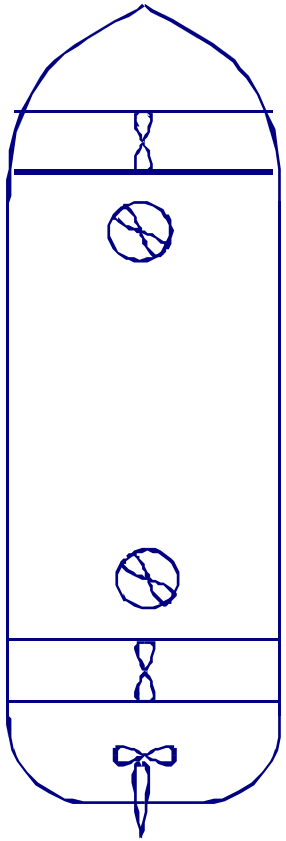
Operational Guideline

Spread Moored Operations
2006 configuration



01 tunnel thruster

01 azimuth thruster

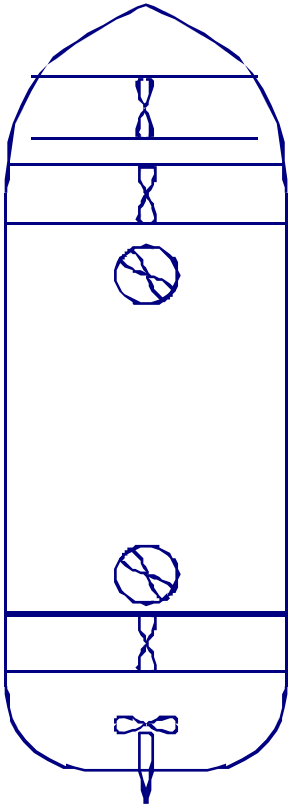
01 azimuth thruster

01 tunnel thruster

01 CPP

01 high lift rudder

Harsh Environmental Operations
2009 configuration



02 tunnel thrusters

01 azimuth thruster

01 azimuth thruster

01 tunnel thruster

01 CPP

01 High Lift Rudder

Operational Guideline

BOW THRUSTER
1.760 kW x 2.750 mm Ø

STERN THRUSTER
1.400 kW x 2.000 mm Ø

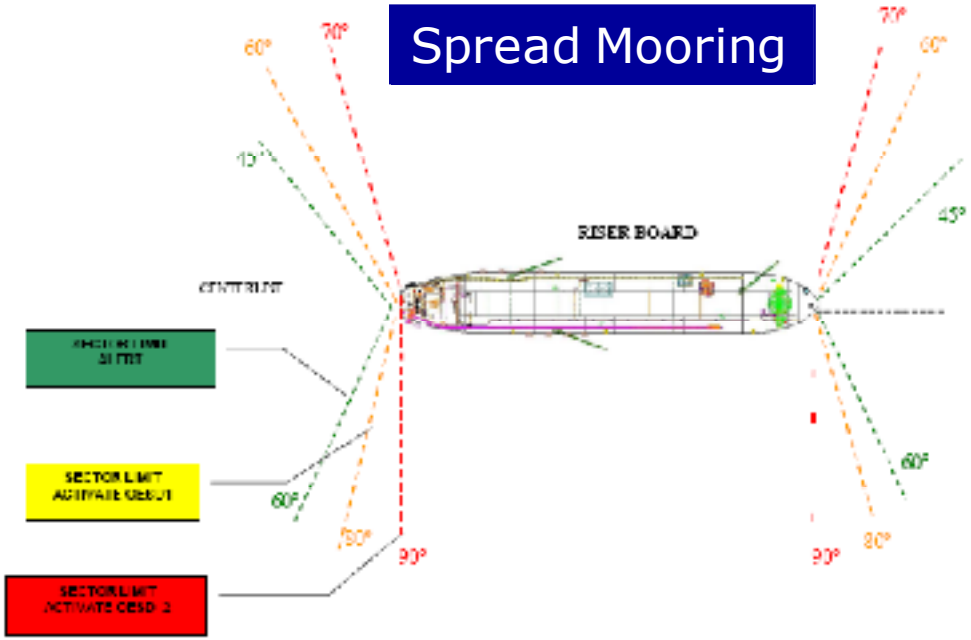
AZIMUTH THRUSTER
2,200 kW
2,600 mm ∅

Item	Enhanced DP Class-1	DP Class-2
DP System	• **Controllers** - DUPLEX configuration	
	• **Sensors** 02 gyros, 02 MRUs, 02 anemometers	
	• Independent **UPSs** for the DP system	
	• **03 PRS** - DARPS, Artemis and Fanbeam	

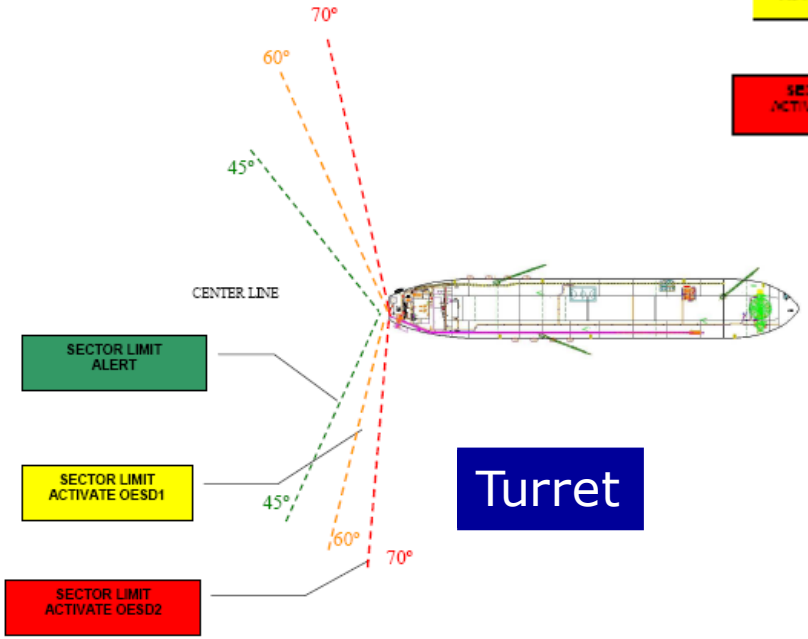
Enhanced DP-1 X DP-2: No differences concerning the traditional ST systems.

Operational Guideline

Spread Mooring



Turret



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Full Scale Measurement

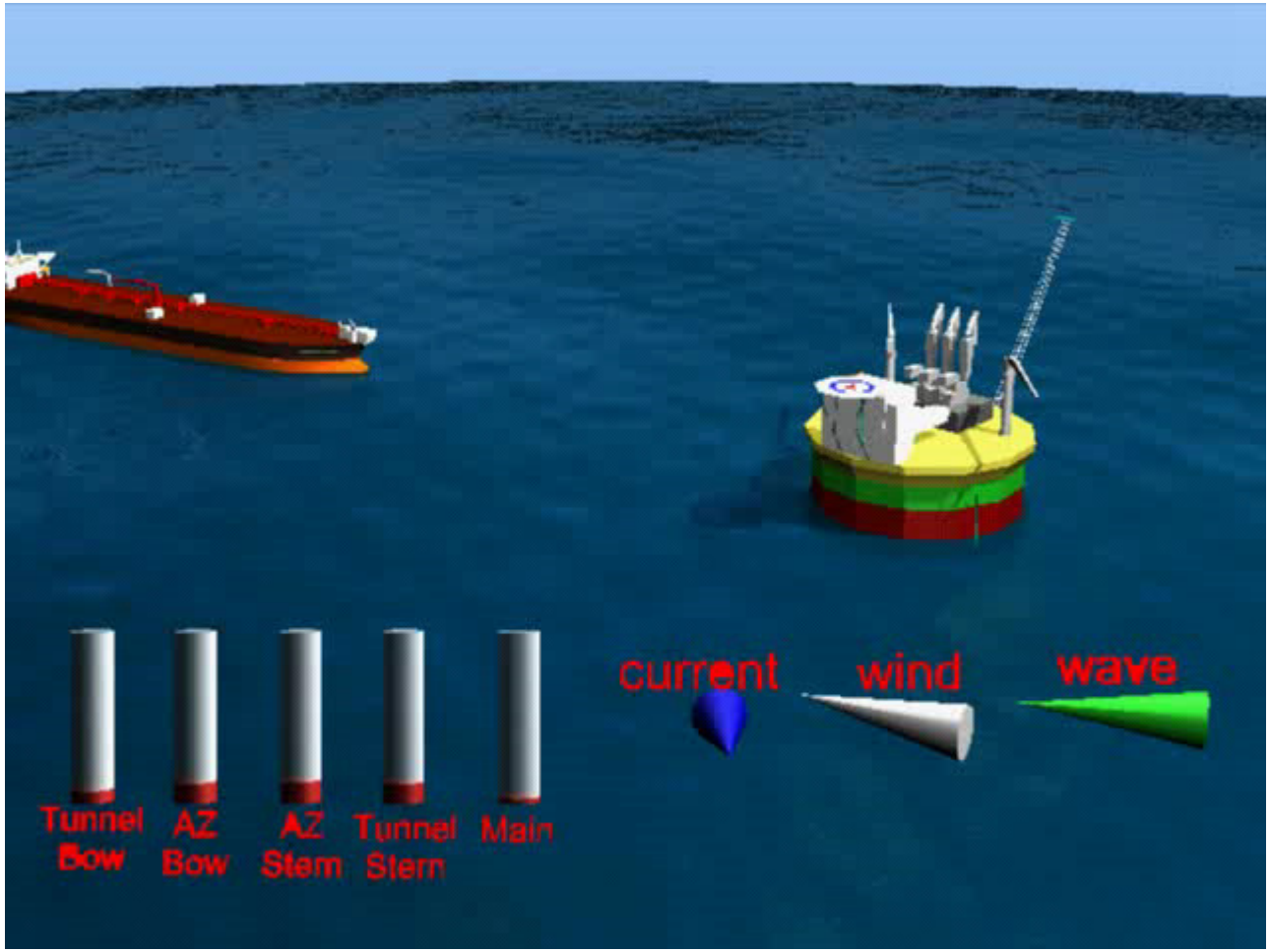
- Full Scale Measurements of DP operations for validation of simulation codes

1st case: offloading of a Monocolumn platform

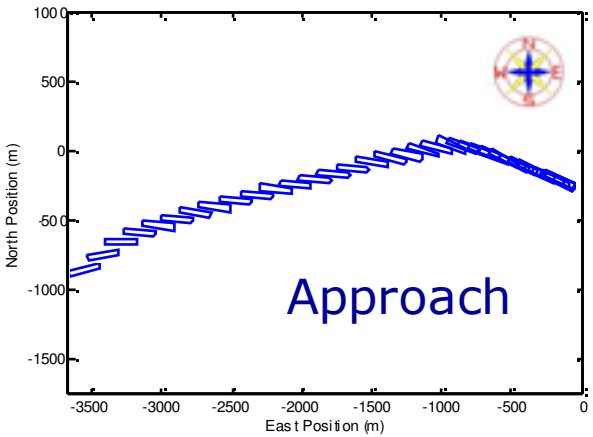
Property	FPSO
Length	65.1m
Beam	65.1 m
Draft Full	18.0m
Draft Ballasted	11.2m
Depth	27.0 m
Displ. Full	54276 MTons
Displ. Ballasted	34315 MTons

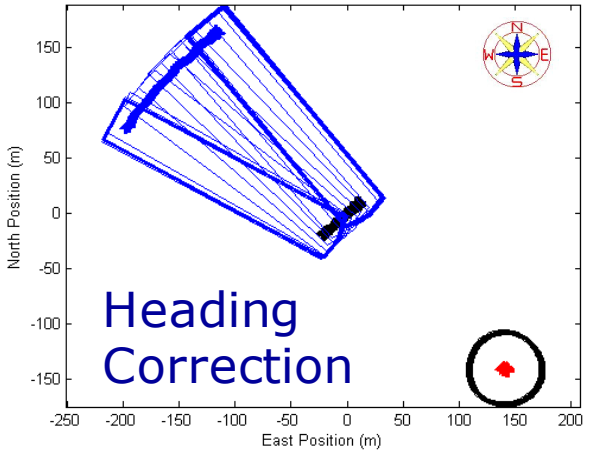
Thruster	Thrust	Power
1- Tunnel Bow	28tonf	1935kW
2- Azimuth Bow	36tonf	2000kW
3- Azimuth Stern	36tonf	2000kW
4- Tunnel Stern	16tonf	1050kW
5- Main Propeller	220tonf	18891kW

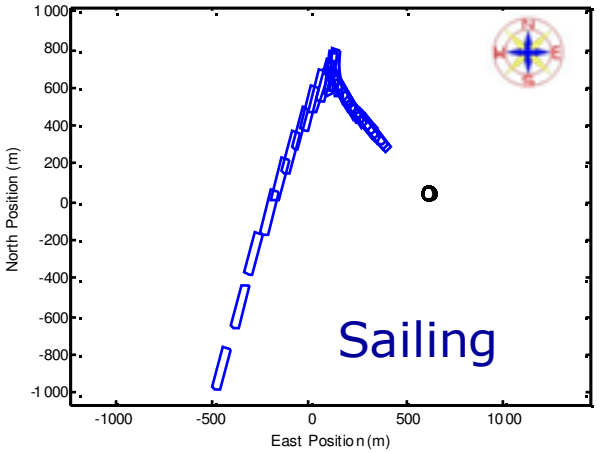
Full Scale Measurement

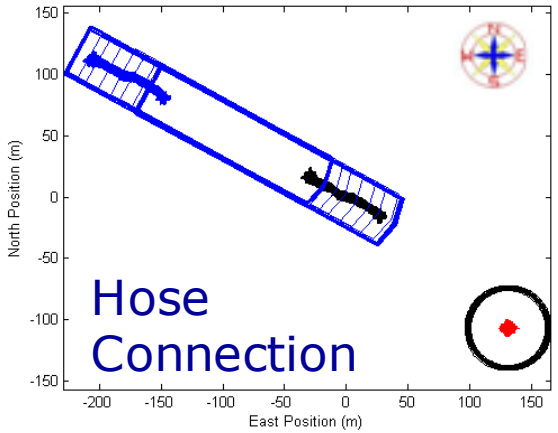


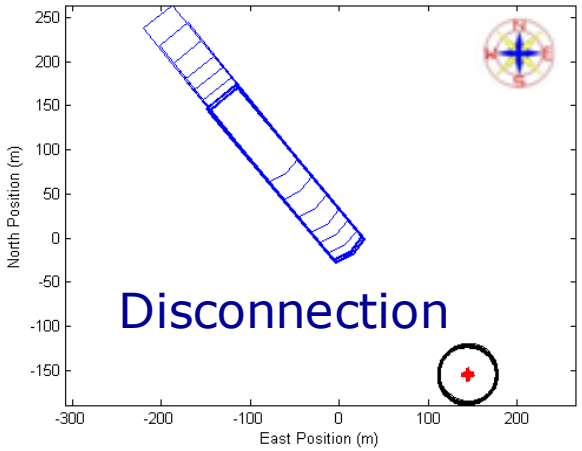
Full Scale Measurement



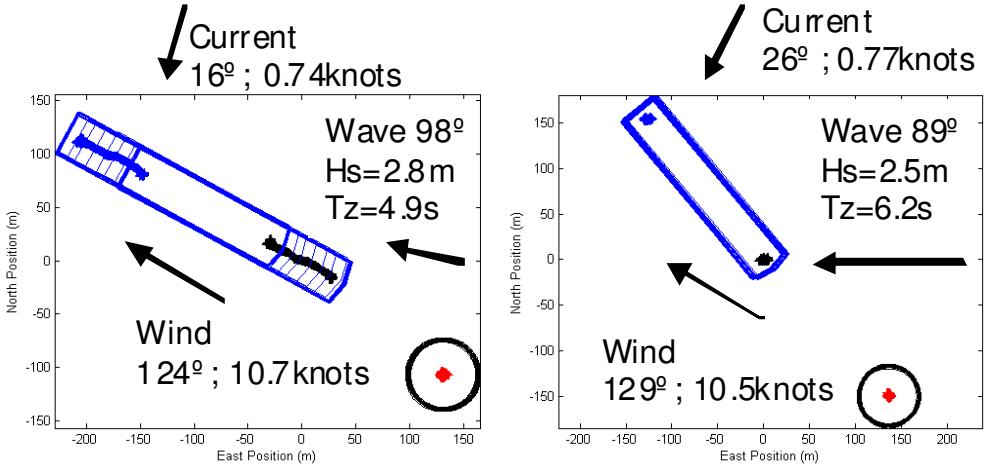






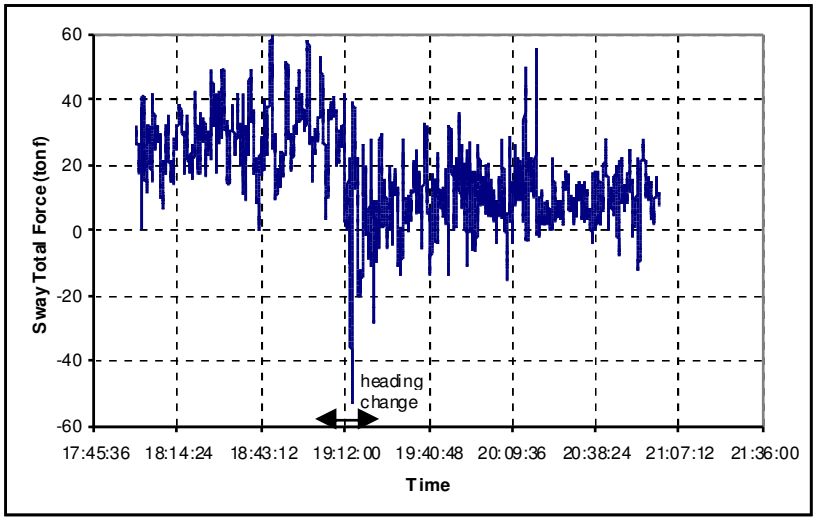


Full Scale Measurement



Heading correction

	Before	After
Surge Thrust (tonf)	4.3	3.1
Sway thrust (tonf)	28.5	10.2
Yaw Moment (tonf.m)	592	306



Sway Thrust

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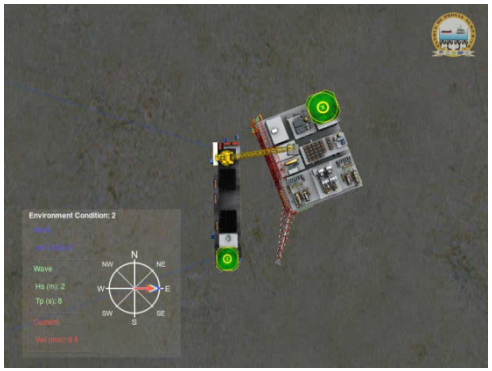
Full Scale Measurement

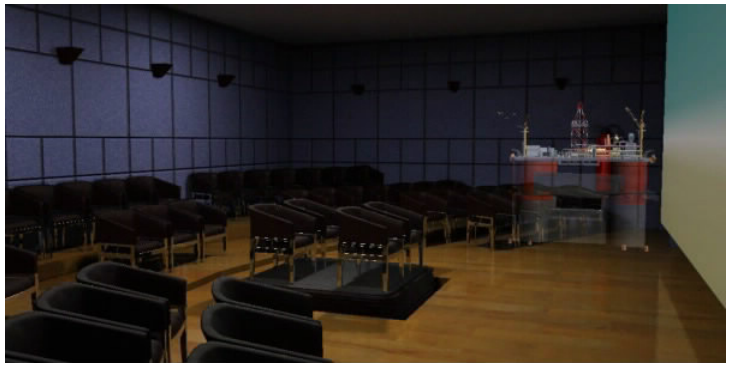
Tanque de Provas Numérico
(Numerical Offshore Tank)

Cluster: 1800 processors;
50 TeraFLOPS

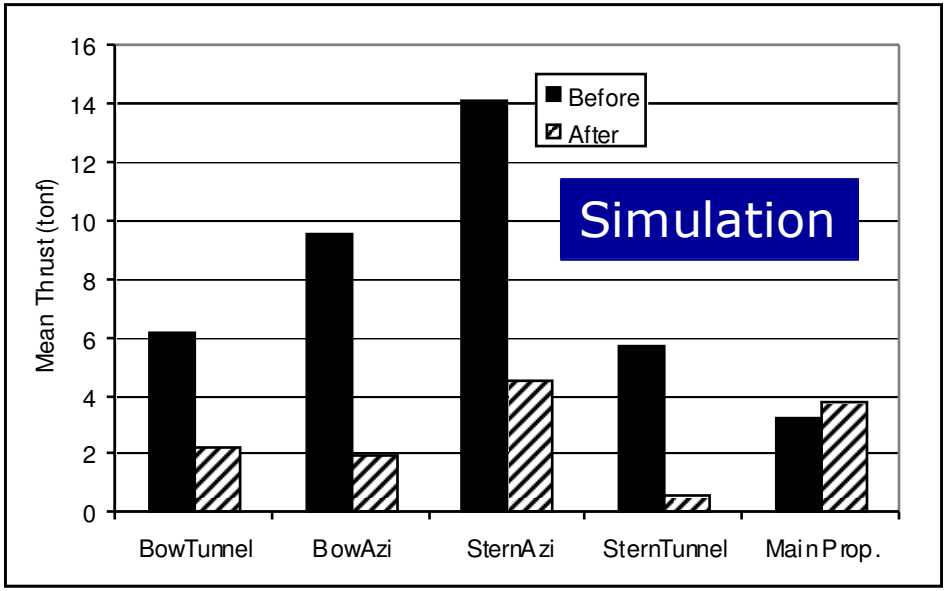
Finite Element Line models
DP System
Multi-vessel dynamics

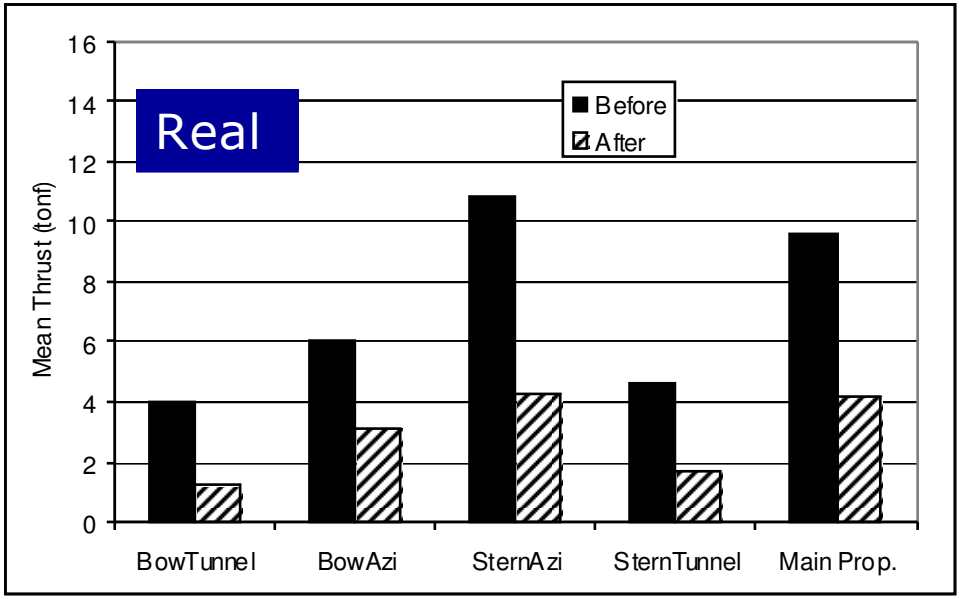


Virtual reality environment



Full Scale Measurement



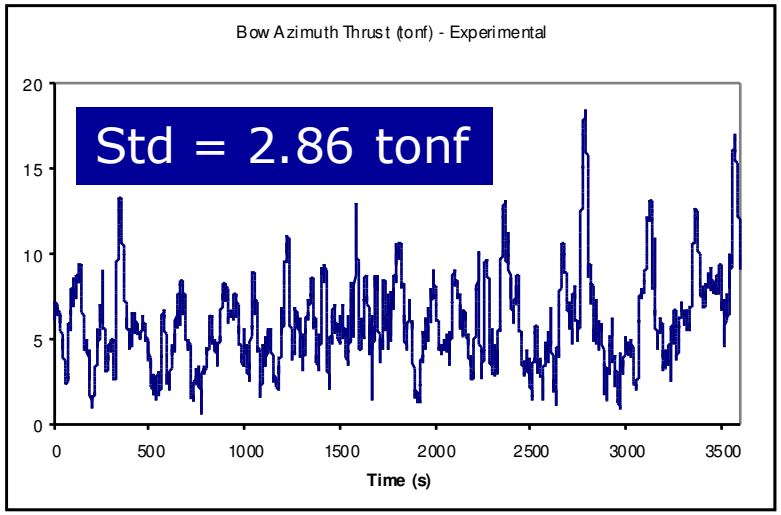


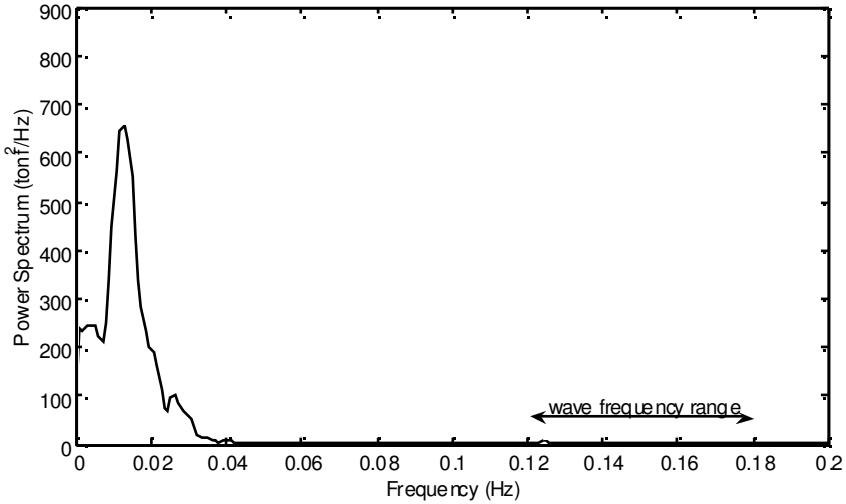
Full Scale Measurement

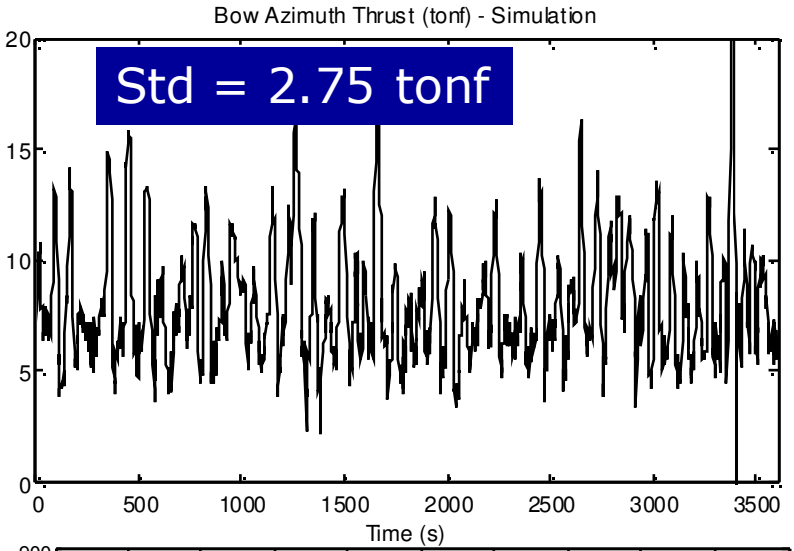
Simulation

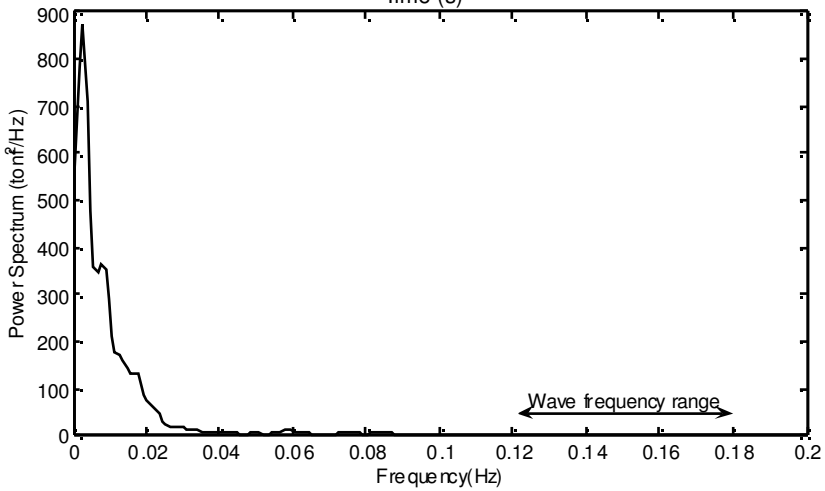
Real

Bow azimuth propeller



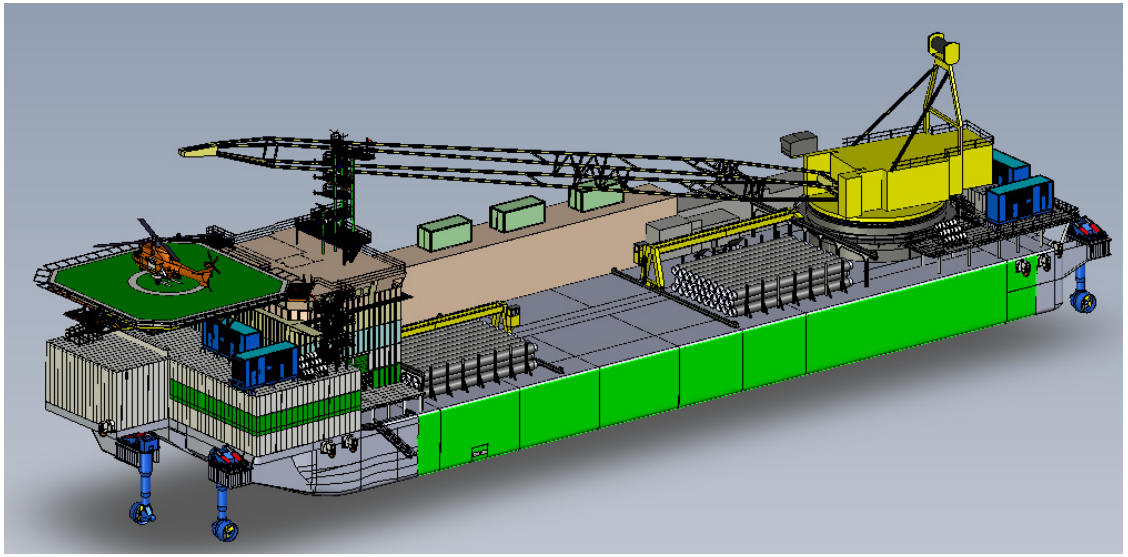






- Next step:

- Validation of a DP crane and pipe-laying barge



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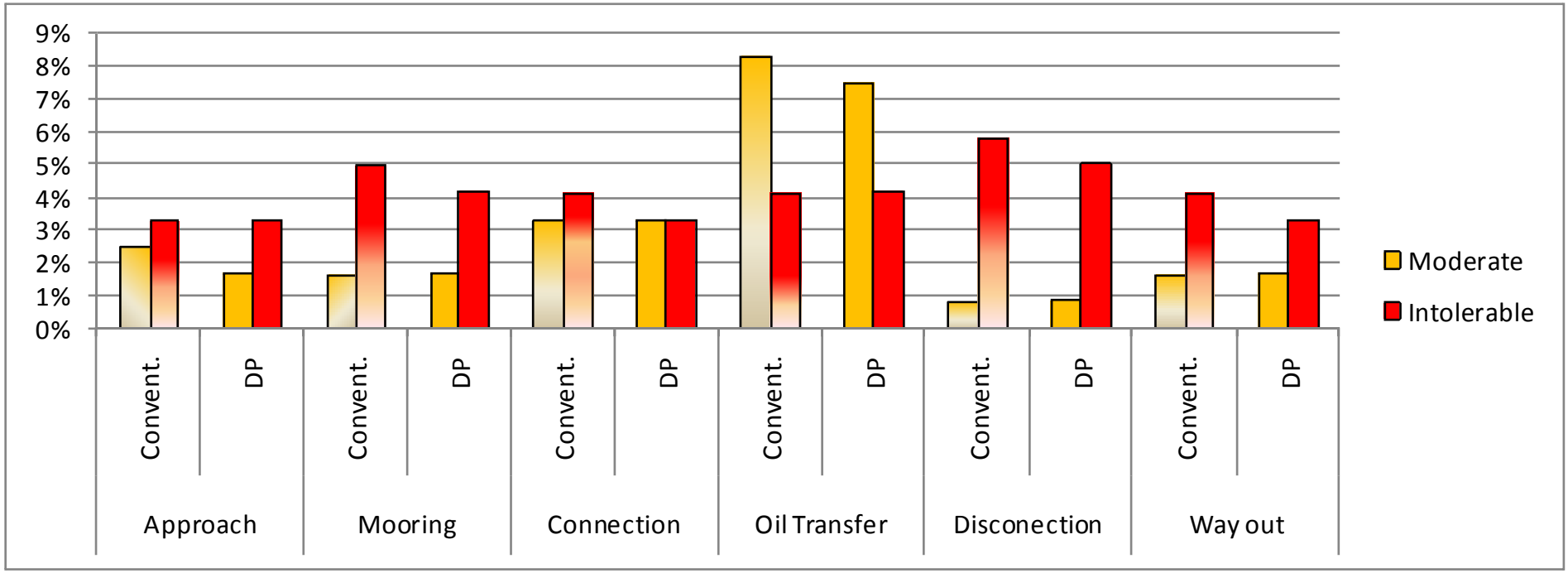
Comparison DP x non-DP offloading

- Utilization of numerical simulator for:
  - Failure / Consequence analysis
  - Environmental Change
  - Downtime Estimation

Comparison DP x non-DP offloading

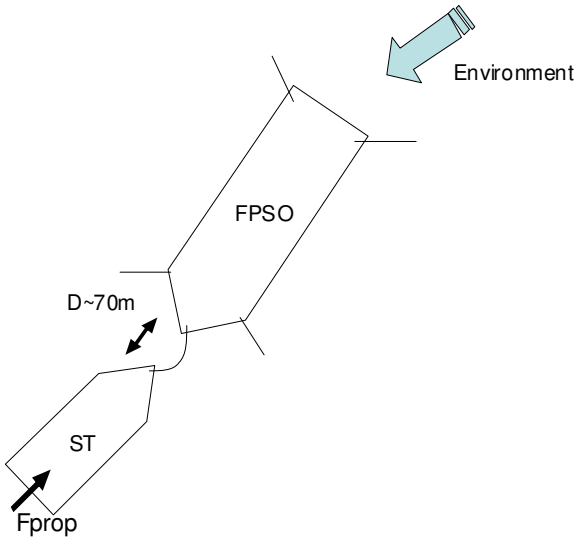
- Failure / Consequence analysis



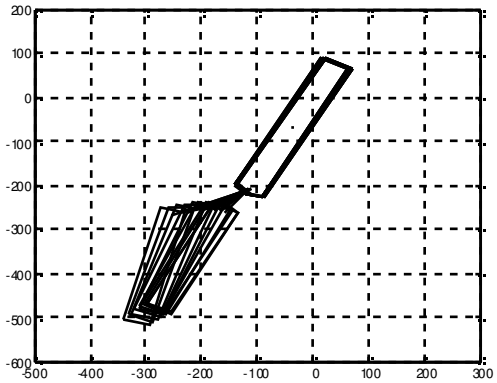
Number of events

Comparison DP x non-DP offloading

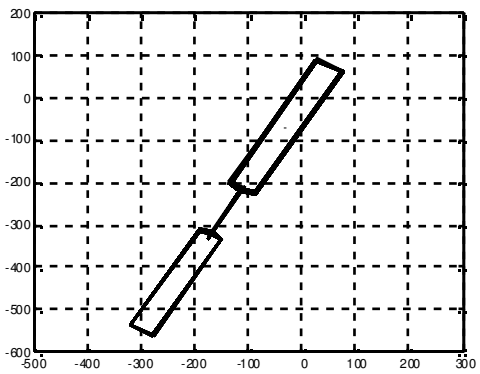
- Failure / Consequence analysis

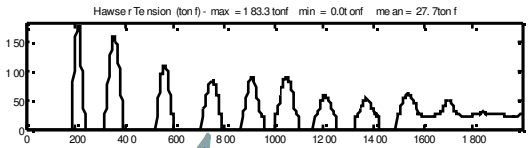


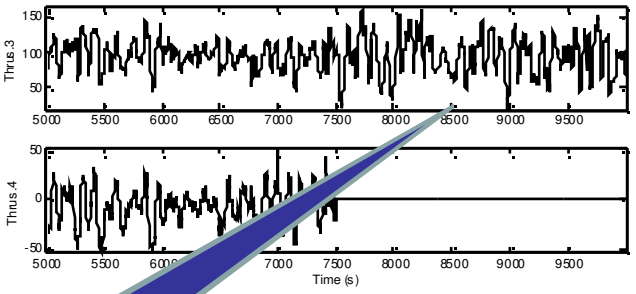
Conventional



DP







Hawser tension

Azimuth thruster

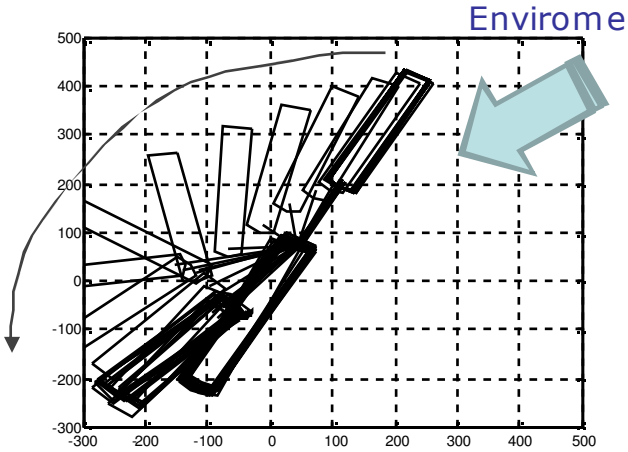
Failure of Main Engine during connection

Comparison DP x non-DP offloading

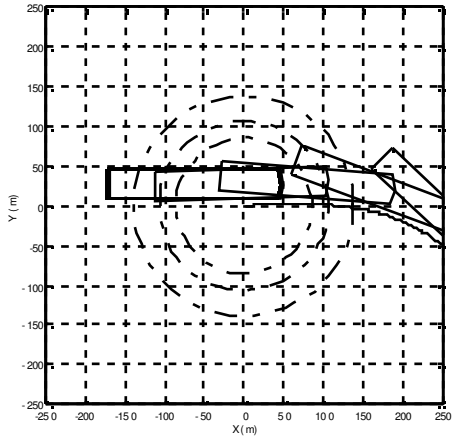
- Failure / Consequence analysis

Typical DP failures

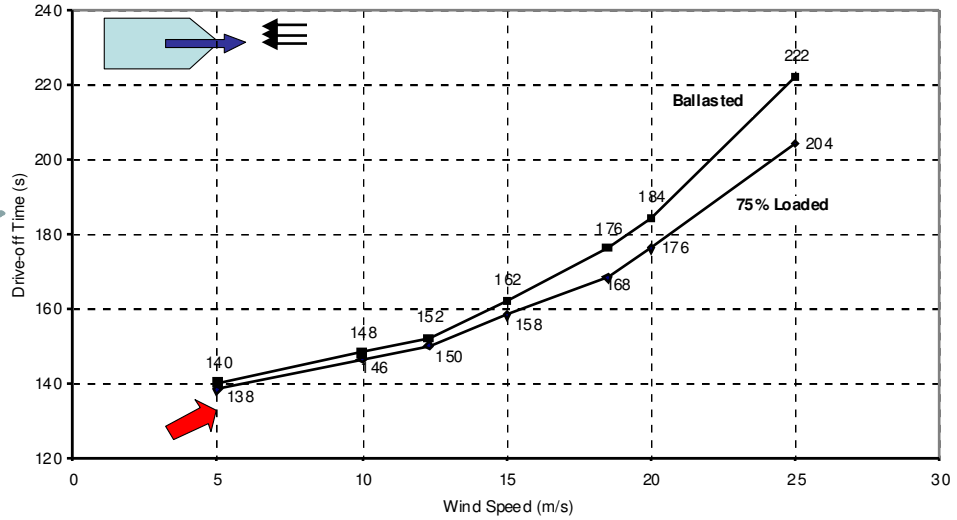
Blackout



Drive off



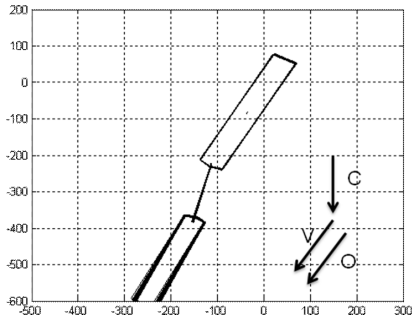
Drive-off into the environment



Time to collision

Comparison DP x non-DP offloading

- Environmental variation



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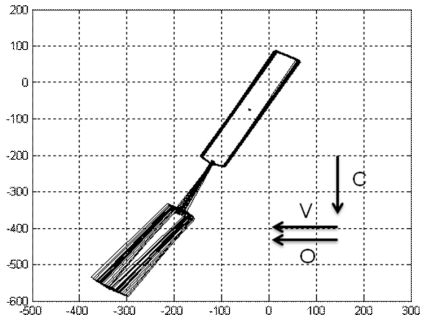

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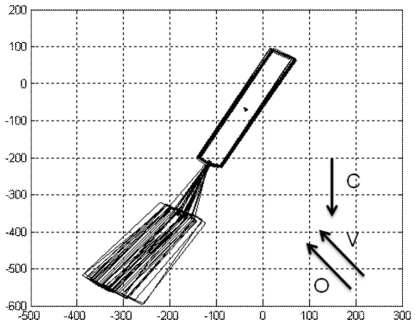

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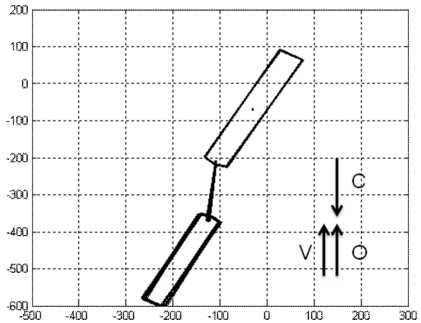

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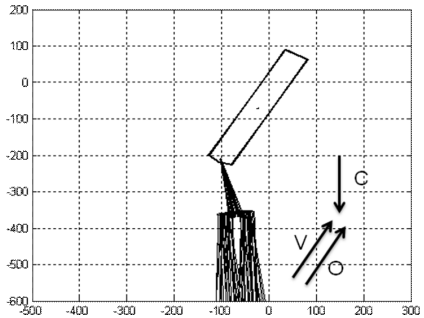

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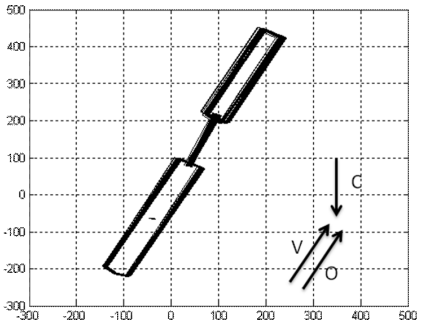
Common variation
Campos Basin

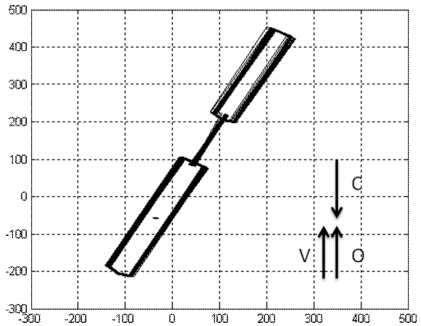
Non-DP Shuttle

Comparison DP x non-DP offloading

- Environmental variation



(1)



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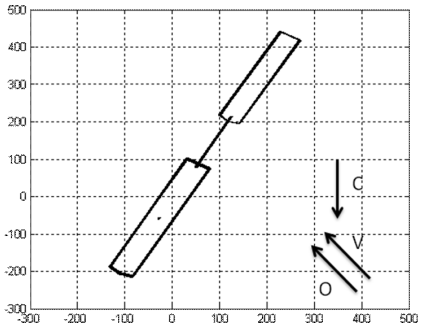

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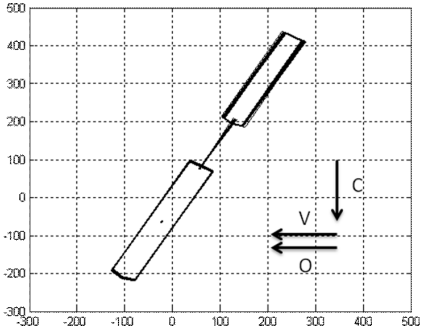

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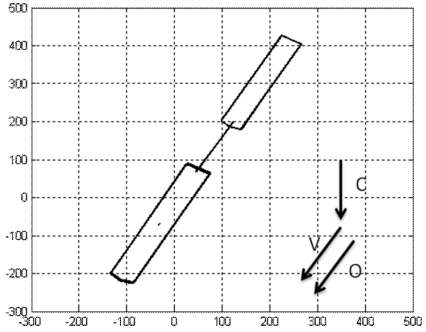


(5)

Common variation Campos Basin

DP Shuttle

Comparison DP x non-DP offloading

- Downtime Estimation

Analysis of Environmental Conditions

Generation of a set of conditions

→

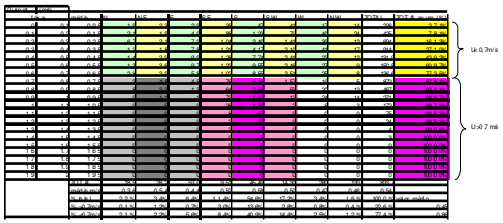
Simulation (Time Domain)

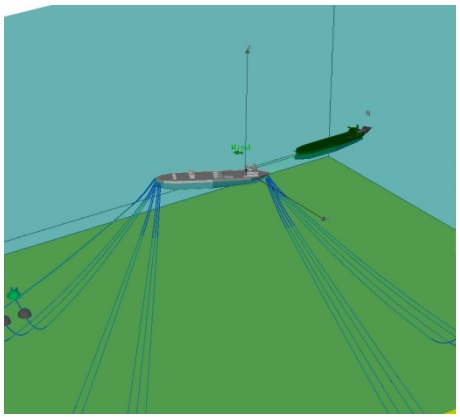
→

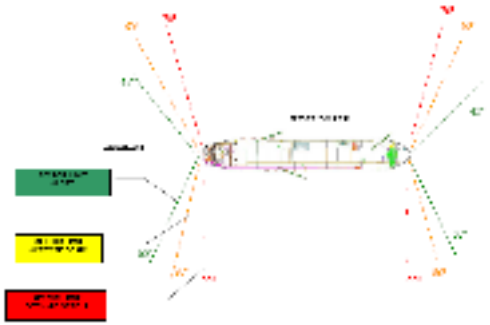
Verification of safety criteria

→

Downtime
Uptime







Comparison DP x non-DP offloading

- Downtime Estimation

FPSO	DPST		Non-DPST	
	Downtime %	Downtime days/year	Downtime %	Downtime days/year
Turret	1.8 to 2.4	7 to 9	2.4 to 3.0	9 to 11
Spread Moored	4.4 to 12.1	16 to 44	18.5 to 26.3	67 to 95

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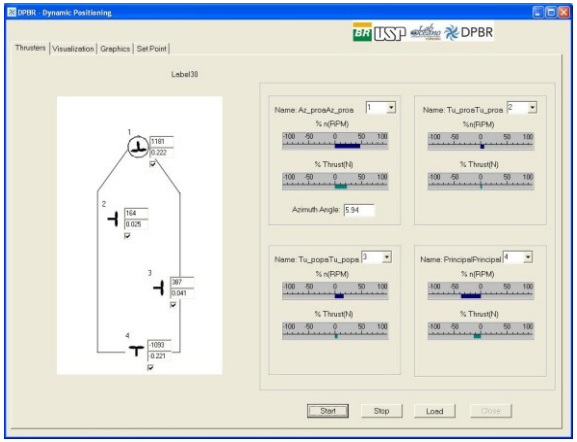
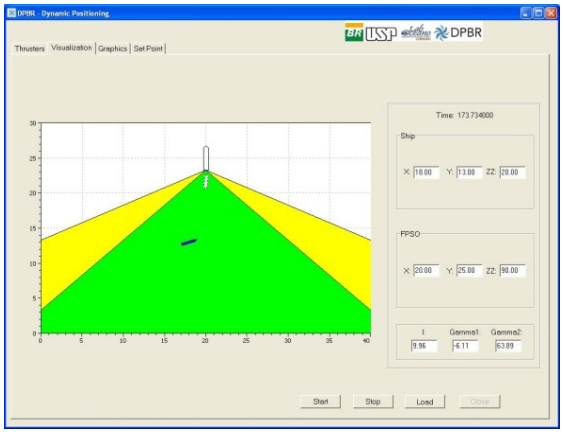
- DPBR – National capacitation for DP tests





- DPBR – National capacitation for DP tests

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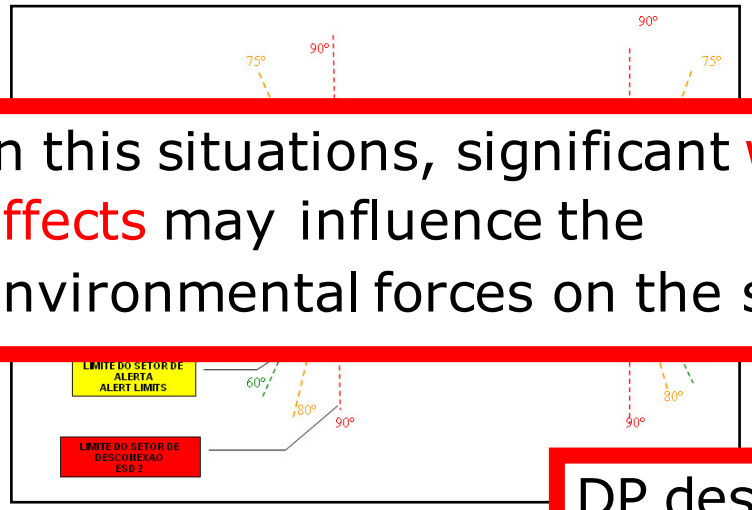
Interaction

Offloading of SMS FPSO: Situations when shuttle is kept close to the borders of operational zone are not uncommon.



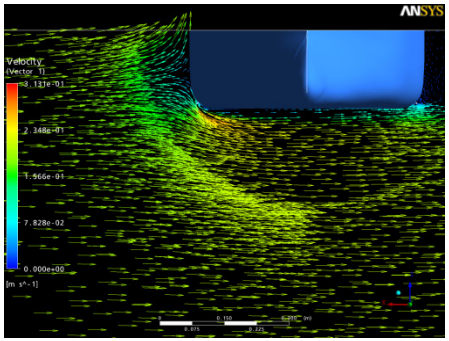
In this situations, significant wake effects may influence the environmental forces on the shuttle

DP design must take such effect into account

•Offloading Operations: Safety criterion demands operation performed by shuttle tankers assisted by Dynamic Positioning (DP) system.

– Current

CFD model

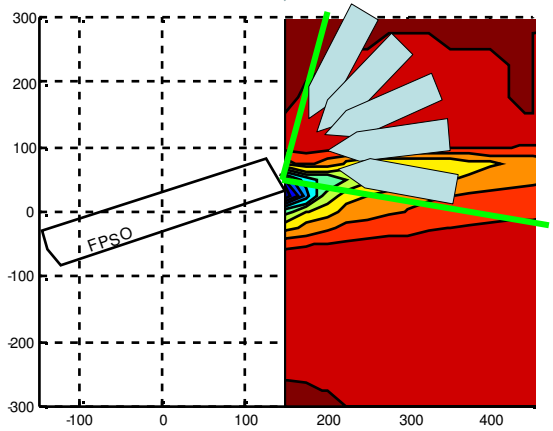


Heuristic Model

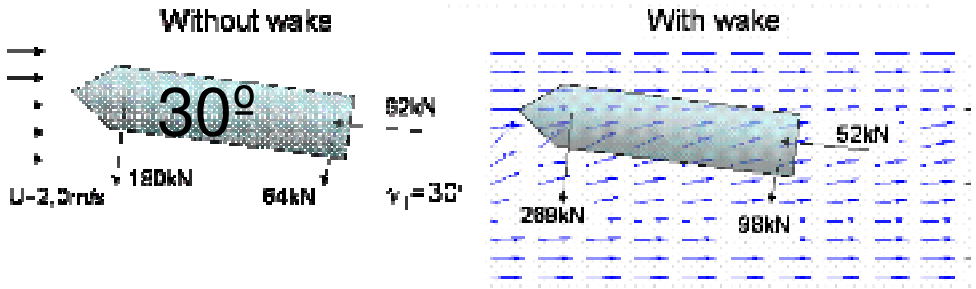
$$F_{X,R}(u',v',r) = \frac{1}{2}\rho\bar{U}^2 T \int_{-L/2}^{L/2} C_{1C}(\alpha'(x))dx -$$
$$-\frac{1}{4}\rho\pi T^2 L\left(\bar{w} + \frac{1}{4}r^2 \int_{-L/2}^{L/2} \cos\alpha'_a(x)dx\right) + M_2\bar{r}$$
$$F_{Y,R}(u',v',r) = \frac{1}{2}\rho\bar{U}^2 T.Y'_v . \int_{-L/2}^{L/2} \text{sen}\alpha'(x)|\cos\alpha'(x)|dx +$$
$$-\frac{1}{2}\rho T \int_{-L/2}^{L/2} C_D(x)(v'(x)+r.x)|v'(x)+r.x|dx -$$
$$-\frac{1}{2}\rho T.L^2.Y'_r.\bar{u}r$$
$$N^o_{Z,R}(u',v',r) = \frac{1}{2}\rho\bar{U}^2 TL\left(N'_v - \frac{\pi T}{L}\right)\int_{-L/2}^{L/2}\left(\frac{1+|\cos\alpha'(x)|}{2}\right)^2 \text{sen}\alpha'(x)|\cos\alpha'(x)|dx -$$
$$-\frac{1}{2}\rho\bar{U}^2 TL\left(\frac{\pi T}{L}\right)\int_{-L/2}^{L/2}\text{sen}\alpha'(x).\cos\alpha'(x)dx +$$
$$-\frac{1}{2}\rho T \int_{-L/2}^{L/2} x.C_D(x)(v'(x)+rx)|v'(x)+r.x|dx +$$
$$-\frac{1}{2}\rho TL^3.N'_r.\bar{u}r -$$
$$-\frac{1}{2}\rho TL^4\left[\frac{C_Y}{16}.|H| - I_3(0,r)r^2\right]$$

Experimental Validation

DP calculation

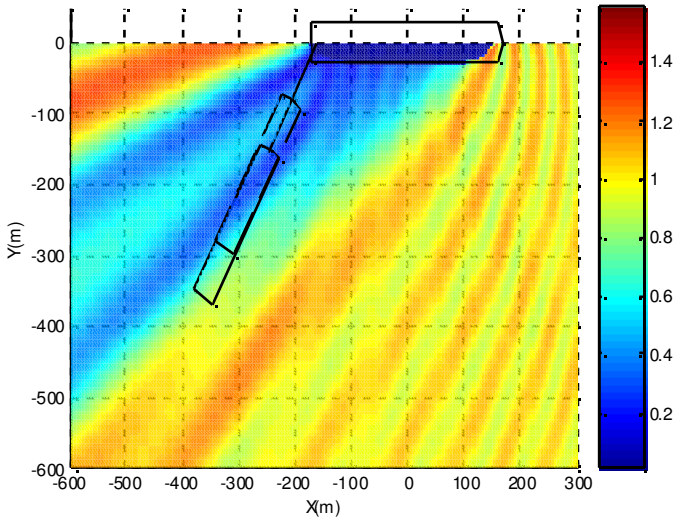


Not considering current wake effect may result up to 5,3% of DP power under-estimation !!!

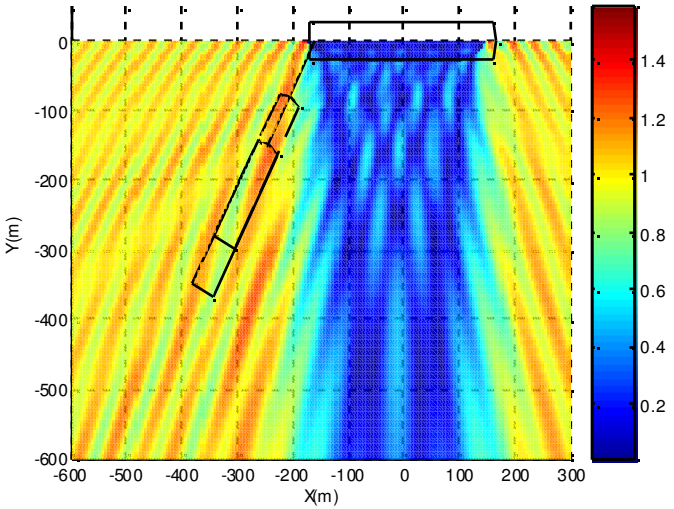


– Wave

Shadow effect computed by potential WAMIT



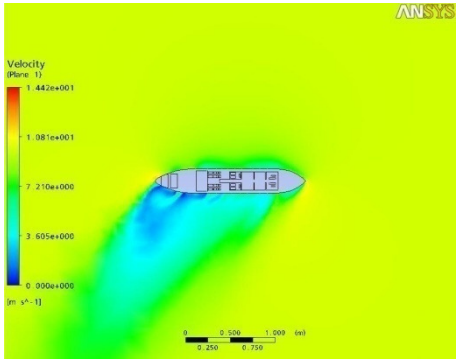
30% overestimation of DP power



8% under estimation of DP power

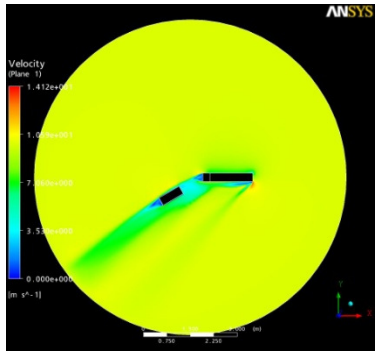
– Wind

CFD model (FPSO only)

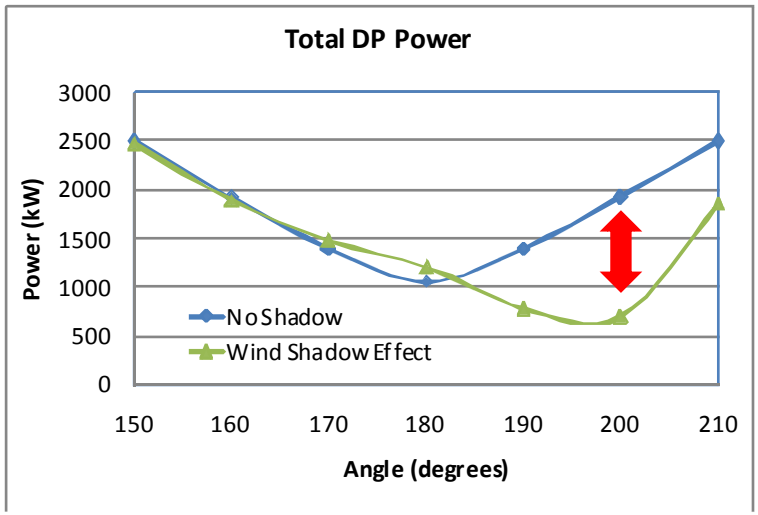


Heuristic Model (still working)

Experimental or CFD Validation



DP calculation



15% total DP power

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FAPESP

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Muito Obrigado!
Thank you!

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