MTS DP Conference
29 September 2004

Wave feed Forward DP and analysis of the effect on Shuttle Tanker operations

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MARIN

MARIN

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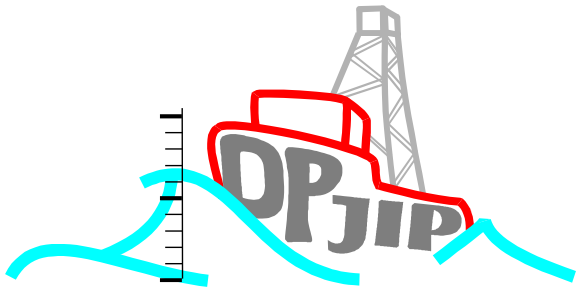
Background



DP –JIP: Joint Industry Project to develop Wave drift Force Feed Forward

Analysis: Quantify the effect on station keeping performance and fuel consumption

Scenario Simulations: Predict the effect on the actual operation

DP -JIP: 2000 - 2003

THE PROJECT

- Full scale measurement campaign
- Development of technology
- Model testing

OBJECTIVE

Enhanced positioning performance by use of wave drift force feed forward

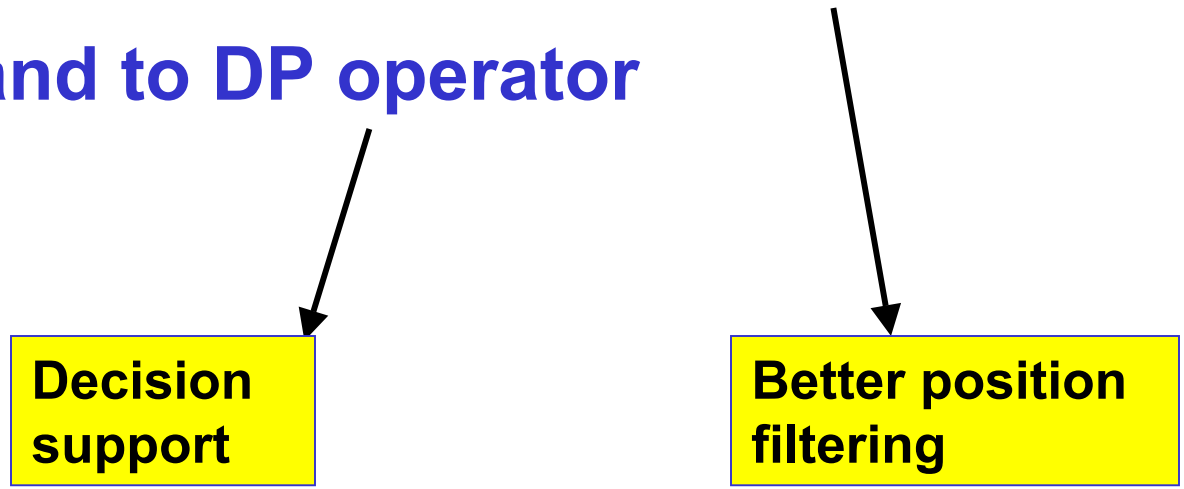
DP -JIP

Technology application:

step 1 Estimate real time wave drift force

step 2 Let thrusters counteract this force

step 3 Give information to Kalman filter and to DP operator



DP-JIP

How to estimate a wave drift force…..

Irregular wave drift forces ~~ Wave groups

Simple case: 2 regular waves with different frequency and phase

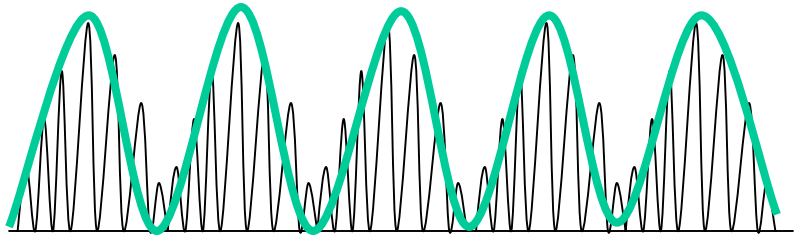
$$\varsigma(t) = \sum_{i=1}^{2} \varsigma_i \sin(\omega_i + \varepsilon_i)$$

$$A^2(t) = \varsigma_1(t).\ \varsigma_2(t)^* = \quad \text{(Hilbert product)}$$

$$= \varsigma_1^2 + \varsigma_2^2 + 2\,\varsigma_1\,\varsigma_2 \cos(\mu\, t + \Delta\varepsilon)$$

with $\mu = \omega_1 - \omega_2$

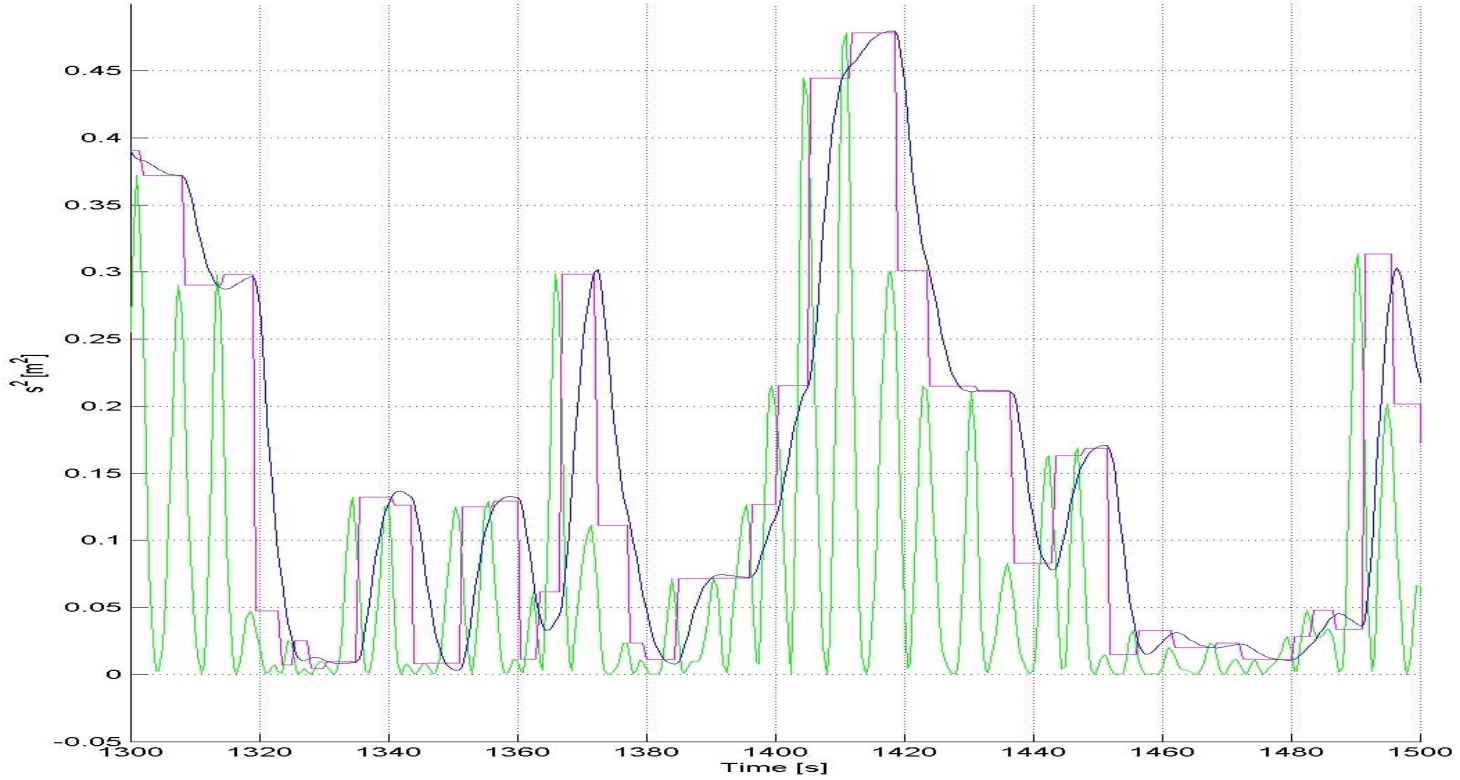
$A^2(t)$



Apply Low Pass filtering of relative wave height squared

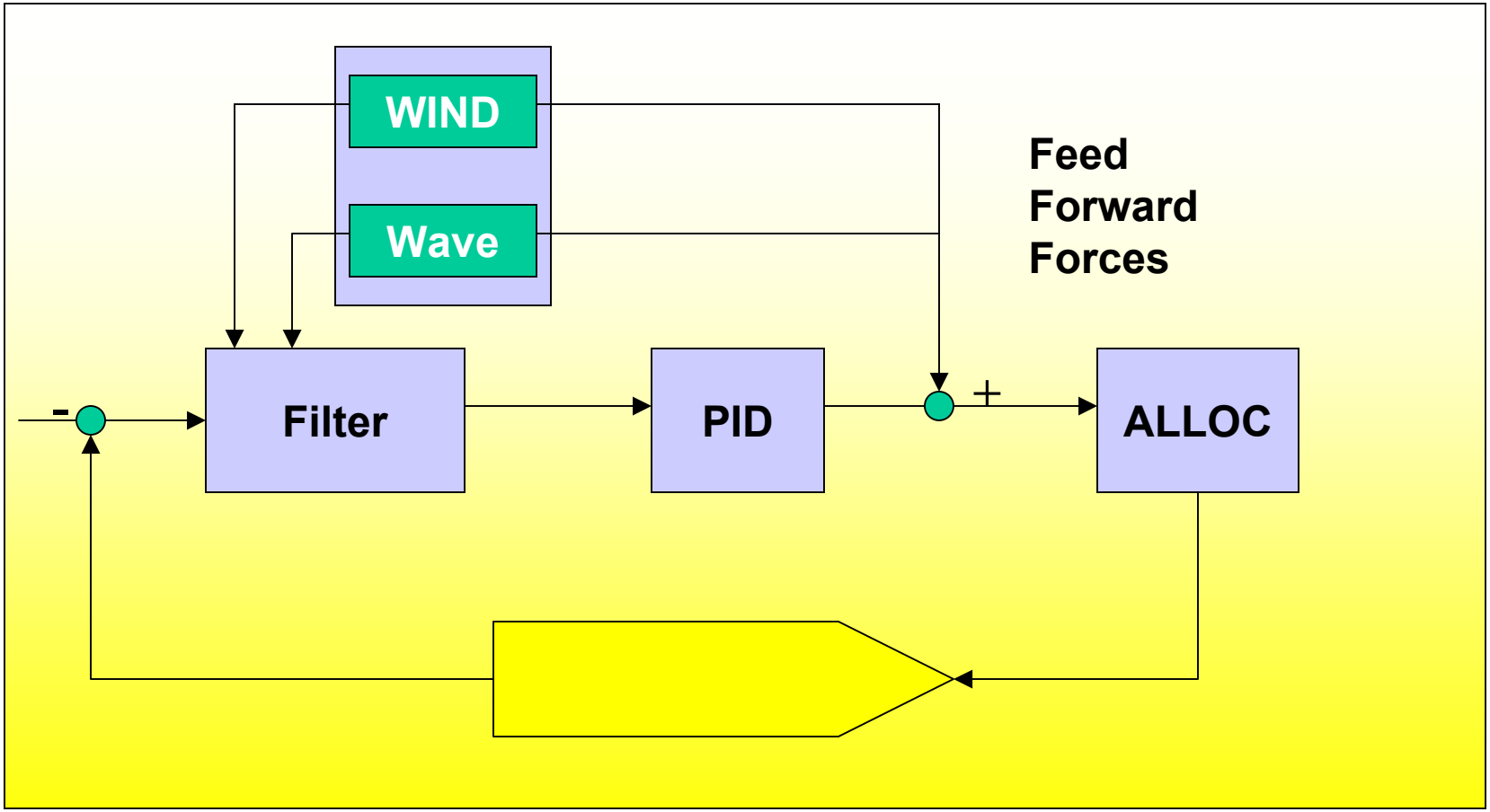
DP-JIP

Time trace of wave squared and envelope filtering method



DP-JIP

Real time estimator “RTEFE” available as plug-on module for DP control system

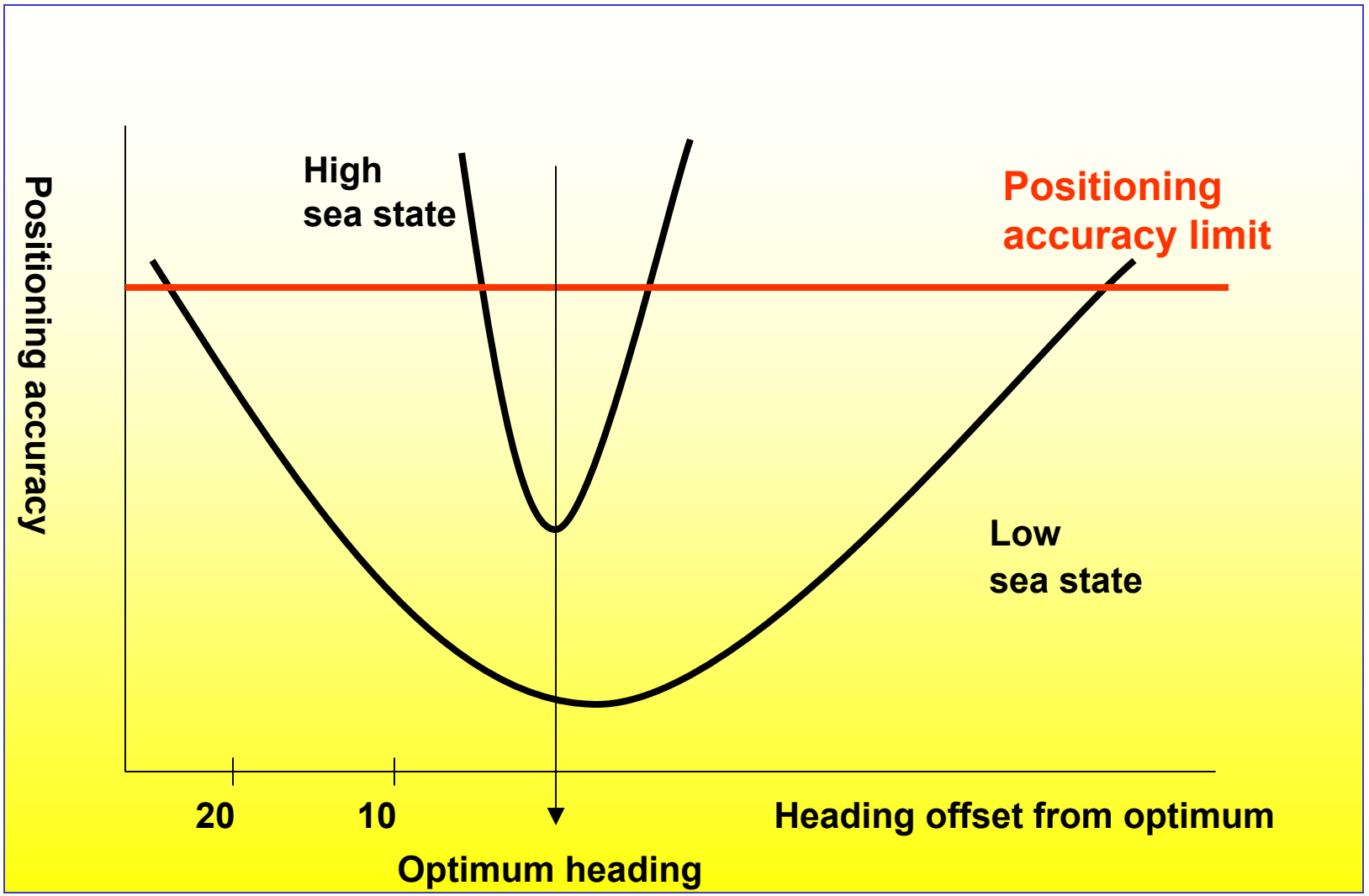


DP-JIP

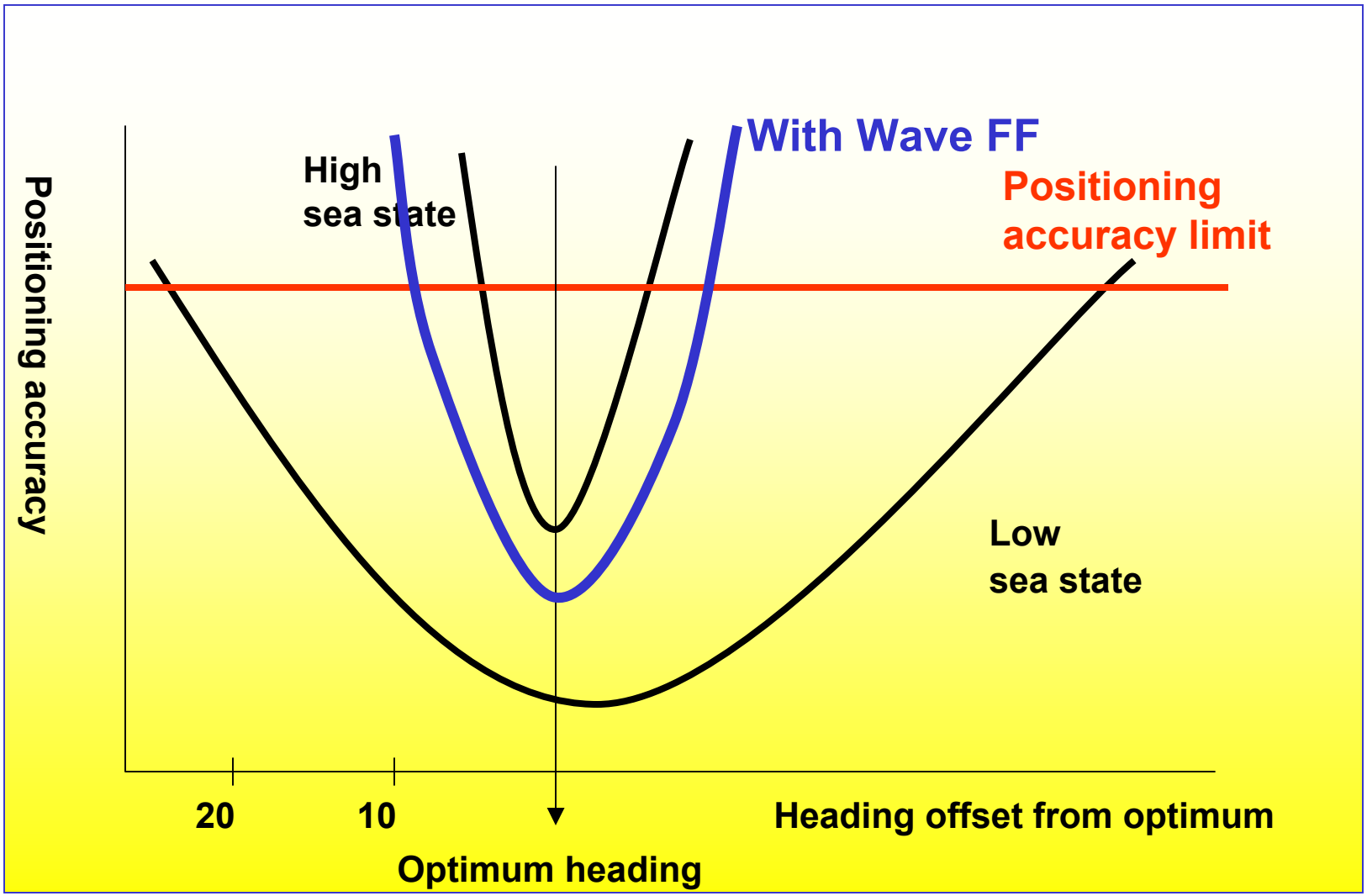
Why apply to shuttle tanker operation?

- **Application of DP to harsh area Offshore Loading requires reliable positioning in high sea states**
- **On large DP vessels the wave drift forces are relatively high**
- **Drift forces increase with wave height squared …**
- **Heading windows get narrower in increasing sea states …**

Heading set point:

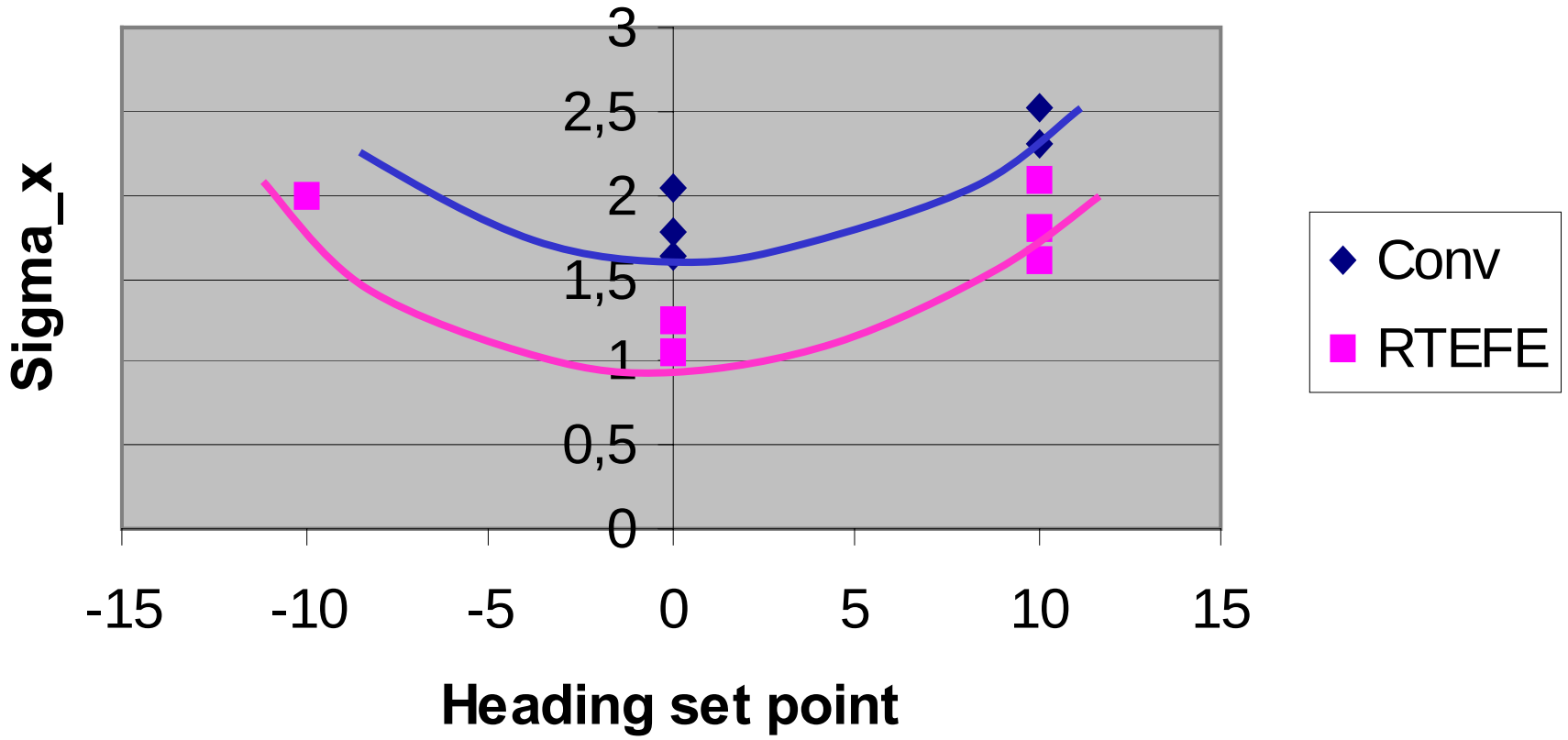


Heading set point: improvement?



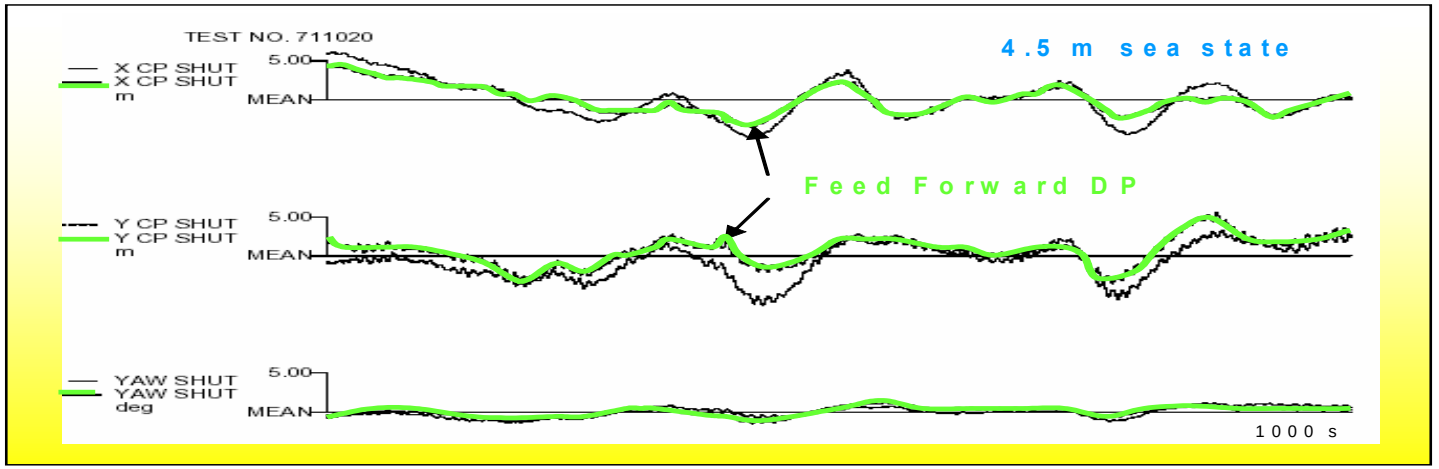
Effect RTEFE on X-pos

Sea State 1: H_s= 4.5 m V_w= 15 m/s

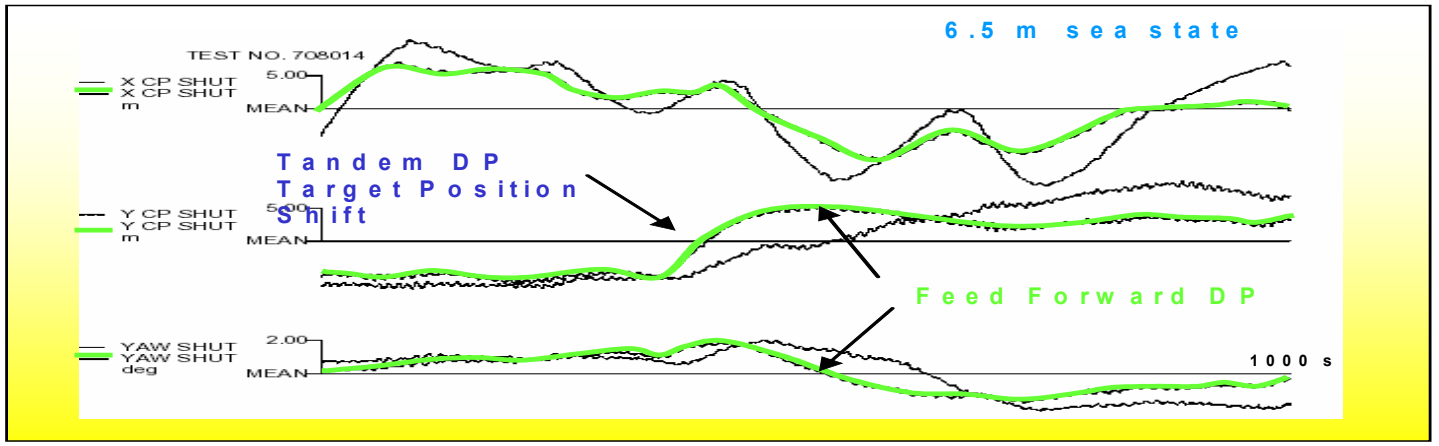


DP -JIP

Positioning time trace with and without Feed Forward shows the benefit to reduce on the larger excursions.

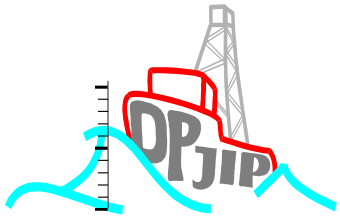


Full DP



Tandem DP

DP -JIP Conclusions



- Wave feed forward for large ships improves positioning accuracy by better reaction to large wave group excitation
- Fuel consumption in the same sea state is equal or slightly less.
- With the same DP system the ship can increase its workability

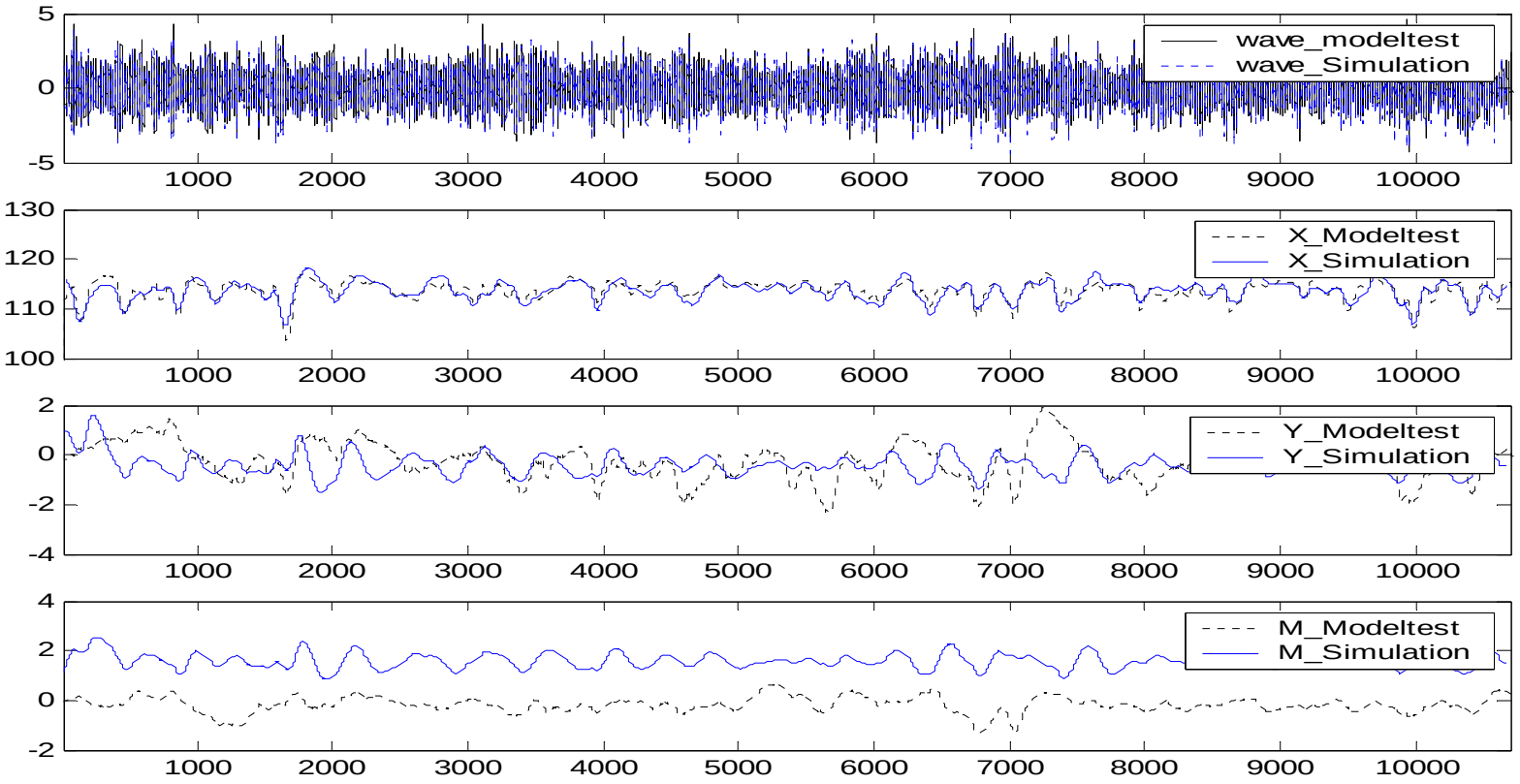
DP-SHUTTLE TANKER APPLICATION

SCOPE

- **Investigate and quantify the effect on the positioning capability**
- **Use of numerical tools: validation**
- **Scenario simulations: criteria and weather**

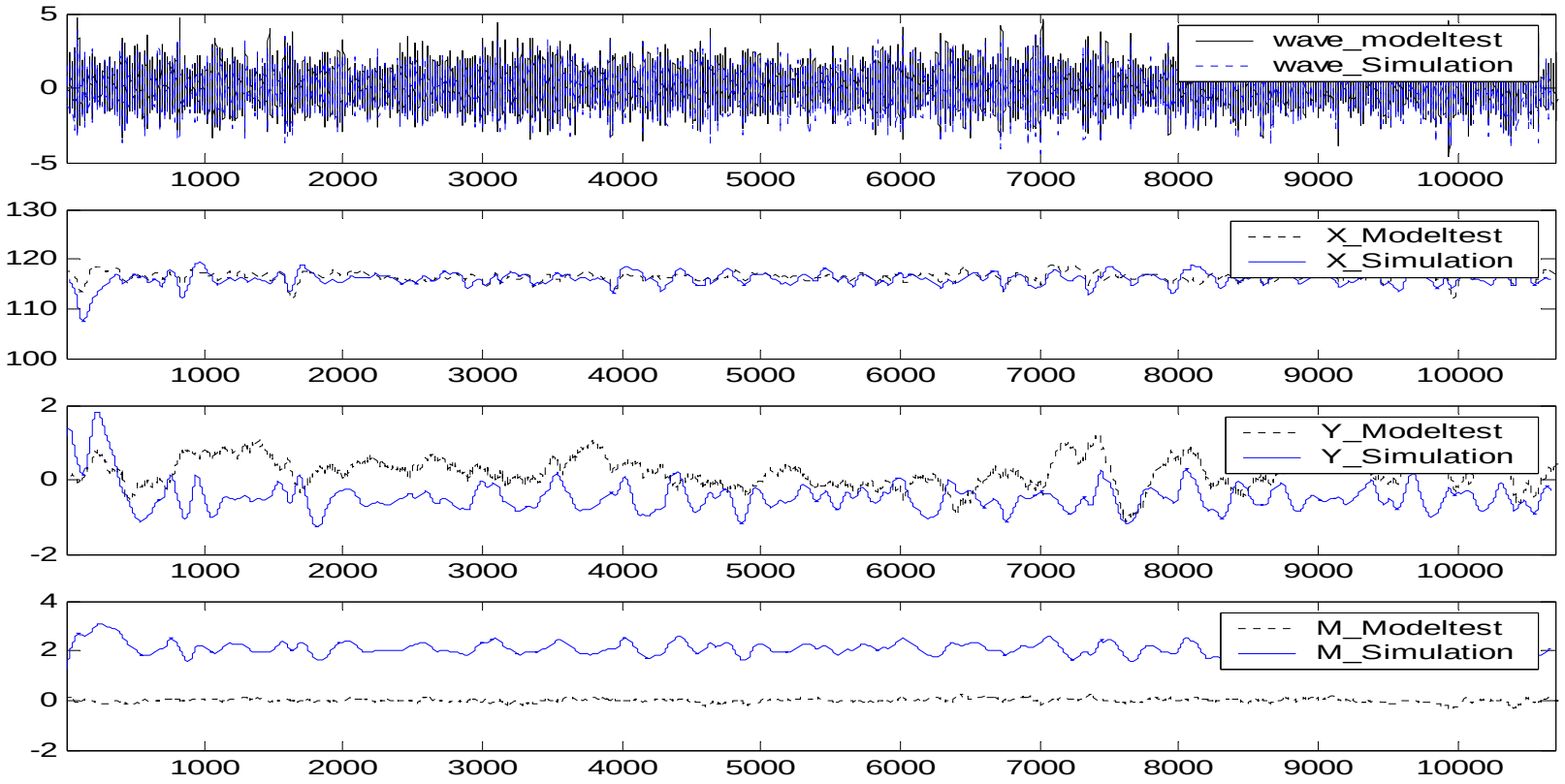
Validation: DP simulation versus model test results

Conventional DP



Validation

RTEFE-DP



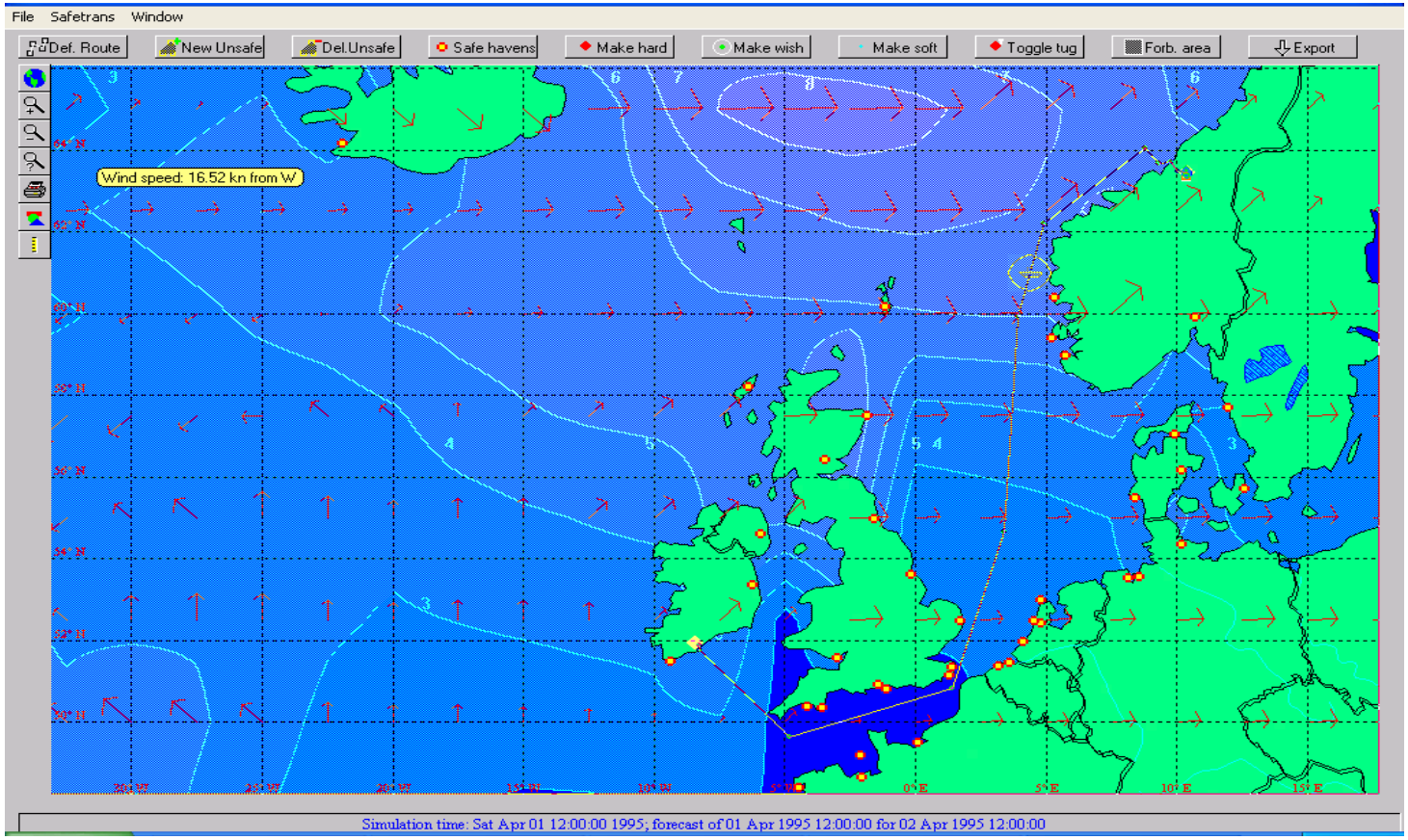
Validation: Model tests versus Full Scale trial

6.5 m sea state with 15 m/s wind

Sea State 4 Loading 19 feb 2002 condition			
Signals (Sig = St. Dev.^{n})	Full Scale measurement	Model test Conv.	RTEFE
Sig_Rm	5.89	5.76	3.11
Sig_Psi	2.76	2.07	1.4
Sig_Y	10.72	6.22	4.69
Sig_BTs Corr	342	126	107
Mean BTs	-44 (Aborted)	-24	-38

Shuttle Tanker operations analysis

SafeTrans: Monte Carlo simulations

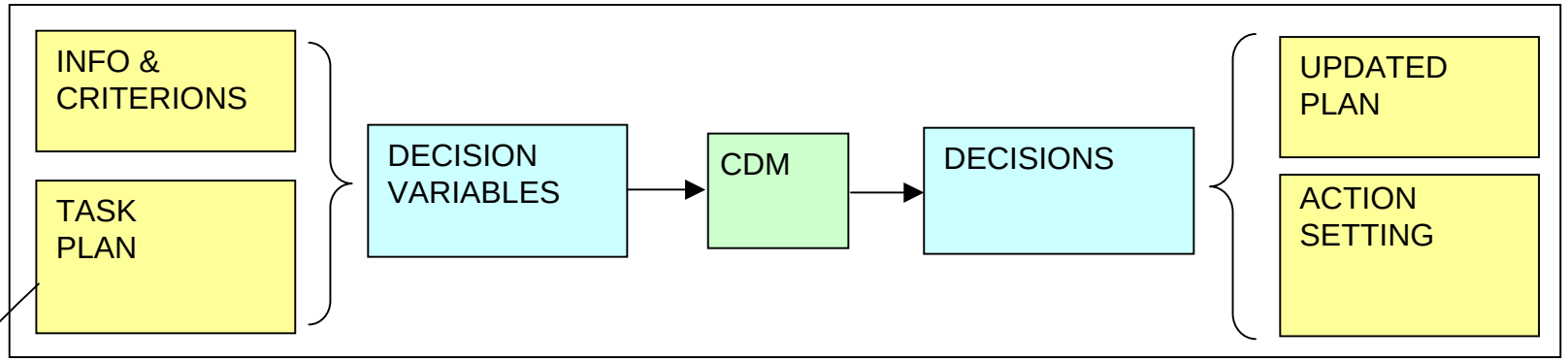


Shuttle Tanker operations analysis

SafeTrans: Monte Carlo simulations

- **Criteria development**
  - **Weather: Start & Stop criterions**
  - **Vessel DP capabilities in weather**
- **Time domain simulations**
  - **3-Hr time steps**
  - **Task plan**
  - **Historic weather 1995-1998**
  - **Captain's decision mimic**
  - **Multiple operation simulations (250)**

Scenario simulations



1. *Approach manoeuvre&connect: 3 hr critical task of preparation of loading operation*
2. *Loading first phase: 6 hr critical task with Shuttle tanker in light draft*
3. *Loading second phase: 6 hr critical task of Shuttle tanker in intermediate draft*
4. *Wait and de-ballast: 60 hr task*
5. *Approach manoeuvre&connect: 3 hr critical task of preparation of loading operation*
6. *Loading third phase: 6 hour critical task with Shuttle tanker in intermediate draft*
7. *Loading fourth phase: 6 hour critical task with Shuttle tanker in deep draft*

Scenario simulations: criterions

Shuttle tanker operation West of Shetlands

- Present operational criterions

  Approach criterion Hs 0 to 4.5m; W 0-40k

  Load criterion Hs 0-6m; W 0-60k

  Time schedule is important

- Can this be improved?

Scenario simulations: criterions

Task No.	Criteria as is				Criteria with RTEFE			
(see list above)	Hs	Vw	F_{BT}	F_X	Hs	Vw	F_{BT}	F_X
	(m)	(m/s)	(kN)	(kN)	(m)	(m/s)	(kN)	(kN)
1	4.5	20	340	450	4.5	20	340	550
2	6.0	30	340	550	6.5	30	340	650
3	6.0	30	340	550	6.5	30	340	650
4	No limits				No limits			
5	4.5	20	340	450	4.5	20	340	550
6	6.0	30	340	550	6.5	30	340	650
7	6.0	30	340	550	6.5	30	340	650

F_{BT} ~~ bow tunnel capacity, allowing a 25% dynamic load.
F_X ~~ wave drift forces.

Operations simulations: Results

			RTEFE
RESULT 250 simulations			
90 -120 hrs	(no loss)		189
121-150 hrs	(1 day loss)		19
151-300 hrs	(1 cycle loss)		30
> 301 hr	See Note		12

Note: Two bad weather periods, i.e. 12-26 feb 1998
and 10-29 dec 1997 caused long non-workable periods

		Actual+	
RESULT 250 simulations			
90 -120 hrs	(no loss)	199	
121-150 hrs	(1 day loss)	15	
151-300 hrs	(1 cycle loss)	23	
> 301 hr	See Note above	9	

+ means that the connect condition has been
increased to Hs=5 m instead of Hs=4.5 m

Operations simulations: Results

Assume 70,000 bbl per day production rate

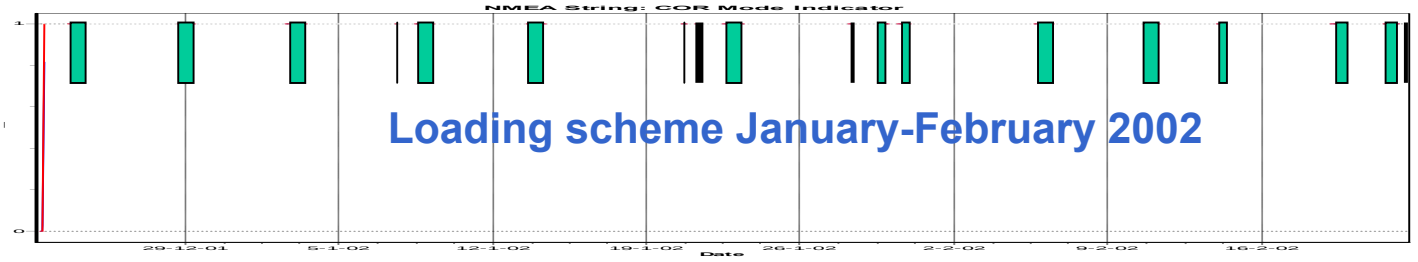
Keeping the connect condition unchanged results in:

- About 3% greater regularity and about 4 days extra production yearly
- About 10 million US$ extra production

Changing the connect condition to Hs=5m (on basis of decision support):

- About 10% greater regularity and about 17 extra production days yearly
- About 40 million US$ extra production

Note: the improvements are largely obtained in the winter half year.



Operations simulations: conclusions

DP simulations with use of RTEFE can be used to compute criteria for offloading operations

Scenario simulations in historic weather can be used to compute potential operations improvements in use of Wave feed forward DP

For a harsh area shuttle tanker operation the economic benefits of using the RTEFE can be substantial

Thank you