NEW APPLICATIONS

Close-In Precision DP Using Wave Feed Forward: STLVAST Phase 2 & 3

Greg Hughes - *Oceaneering International*
Rick Harris, - *MAPC*
Frans Quadvlieg, Rink Hallmann - *Marin*

October 13 -14, 2009

Dynamic Positioning Committee
Marine Technology Society

Return to Session Directory

New Applications

Close-In Precision DP using Wave Feed Forward: STLVAST Phase 2 & 3

Greg Hughes, Oceaneering International
Rick Harris, MAPC
Frans Quadvlieg, MARIN
Rink Hallmann, MARIN

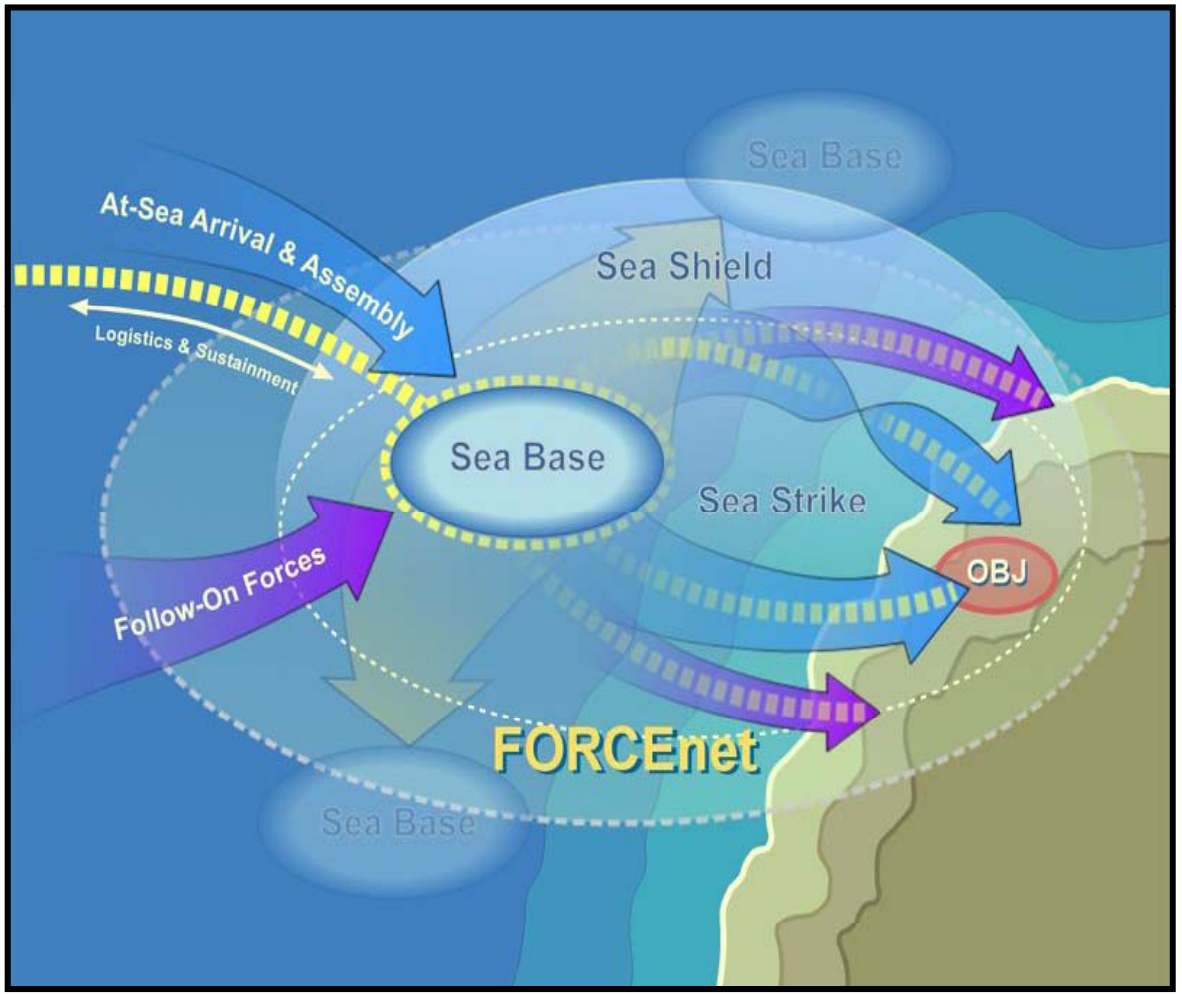
Who

An ONR Science & Technology Program led by Oceaneering as prime contractor, with a multi-national, multi-talented team:

- Research & Engineering analysis
- Test Facility, Data Analysis, Simulation
- DP Control System Consulting
- Two Ship Simulations Using LAMP

Why

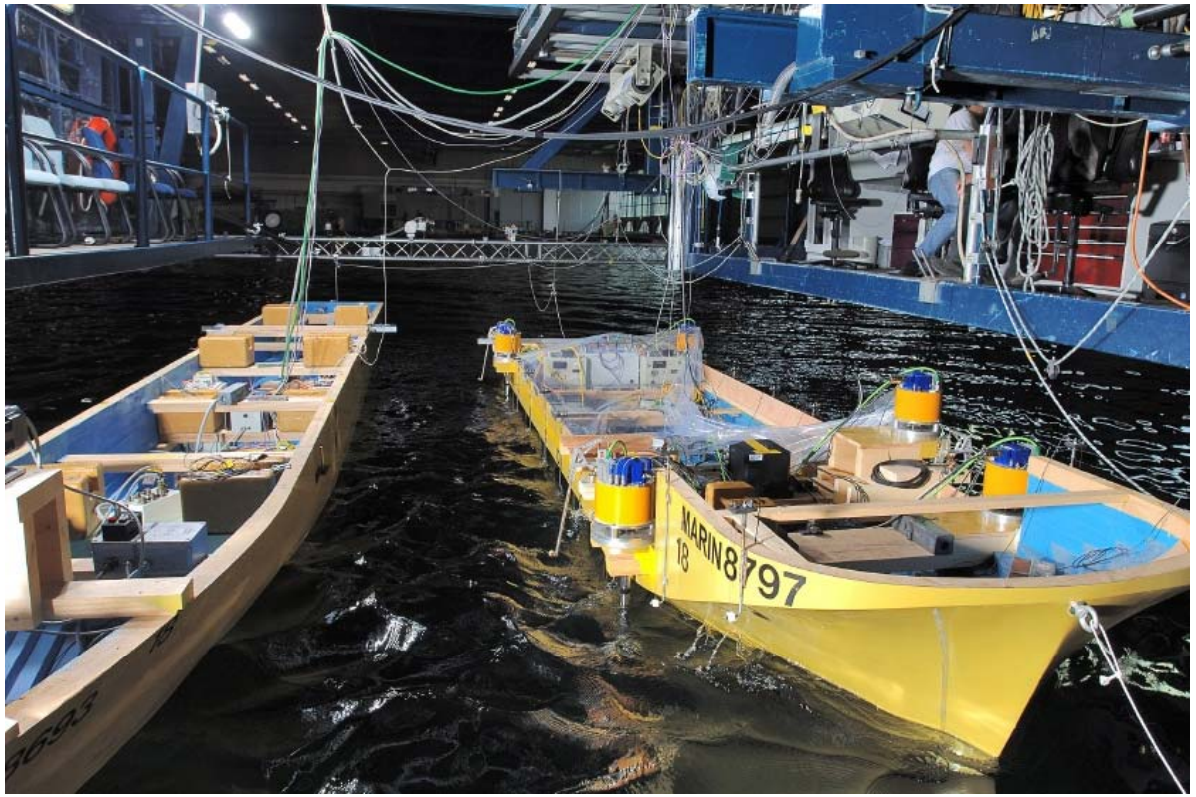
To support the movement of supplies (by vehicle or crane) between vessels, at sea, in the Sea Base



What Does That Mean

Two large vessels, running side by side, for the movement of personnel, materiel and containers:

- At up to 4 Knots
- As close as 15-25 Ft
- Sea State 3 and 4
- Only the “active” vessel has full DP



STLVAST Challenges

Vessel Architecture

- Cannot be changed, so technology seeks to improve the positioning capability of a large monohull with azimuthing thrusters.
- Surrogate MLP is the Mighty Servant 3, with 5 Thrustmaster portable azimuthing units added (about 2MW each).

Physics

- Second ship creates wave diffraction and ‘bank’ effect.
- Ahead speed increases sway/yaw coupling.
- Reduced ship separation requires tighter positioning.
- Thruster effectiveness drops away at 4+ knots.

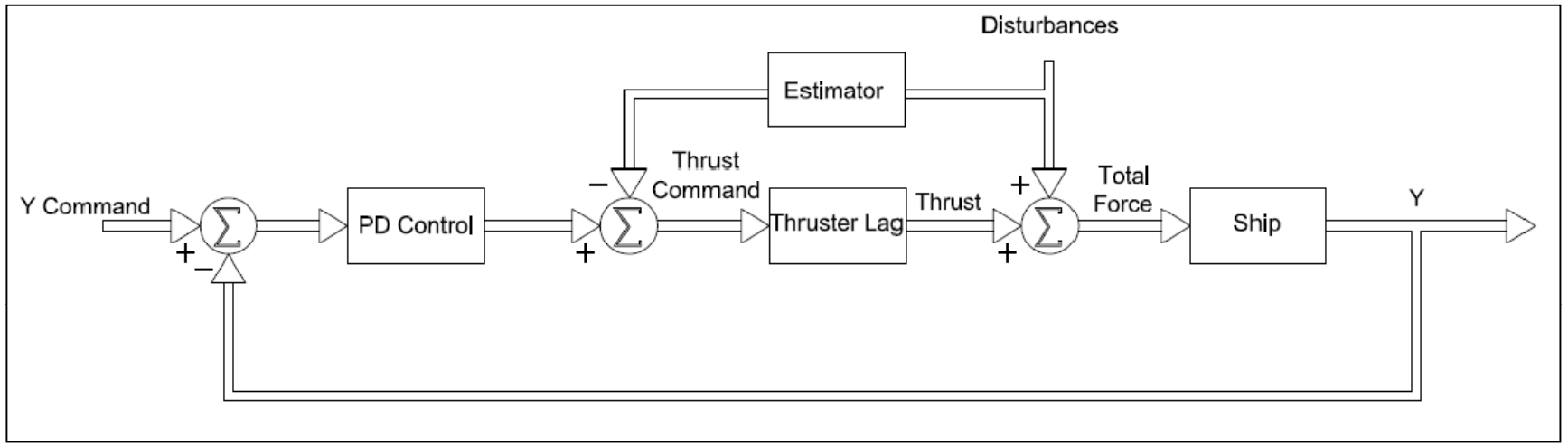
Wave Feed Forward

Phase 2 sought to improve MLP positioning accuracy using only new sensors and control algorithms, thereby providing a capability that can be easily retro-fitted to existing DP vessels.

Wave Feed Forward offers just such a potential capability and was first promoted by J.A.Pinkster and colleagues at NSMB (MARIN) in the late 1970's. Recent work includes a 2003 Joint Industry Program, that included our Teammates KOS and MARIN.

- Use wave height sensors around the hull to measure local relative waterline elevation.
- Calculate in real time the drift forces in surge, sway and yaw using the waterline integral method developed by Pinkster and colleagues.
- Feed the estimated drift forces forward in the DP control loop, to counter the real drift forces, before the vessel position error grows.

Feed Forward Control



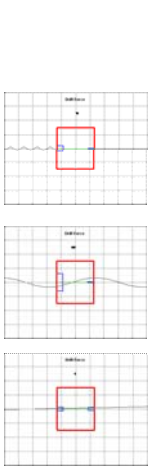
Using feedforward *and* feedback control combines the advantages of both.

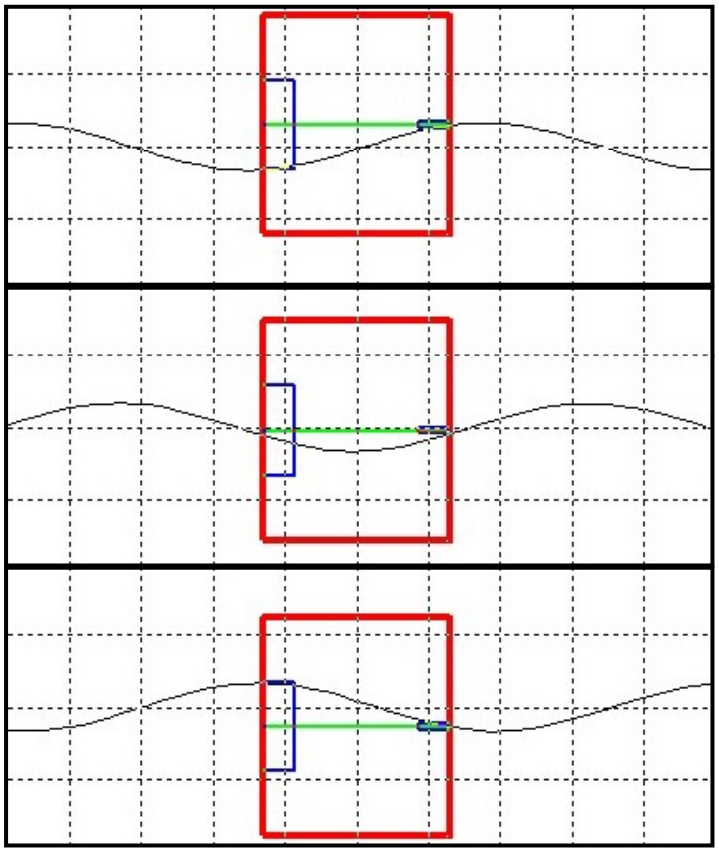
- Feedback provides robustness to ship and disturbance uncertainties.
- Feedforward improves disturbance rejection without high feedback gains.

But, to be effective feedforward control requires an accurate estimate of the disturbance.

Wave Loads

- First order wave loads.
  - Proportional to wave amplitude
  - Zero mean
  - Wave incidence frequency
  - ***Cannot*** be controlled by DP systems
- Second order wave loads
  - Proportional to wave amplitude squared
  - Nonzero mean
  - Components below wave incidence frequency
  - ***Can*** be controlled by DP systems





Key to successful wave feed forward DP is accurate estimation of low frequency and steady second order wave loads – "wave drift".

Wave Load Estimation

Pinkster's Waterline Integral Method

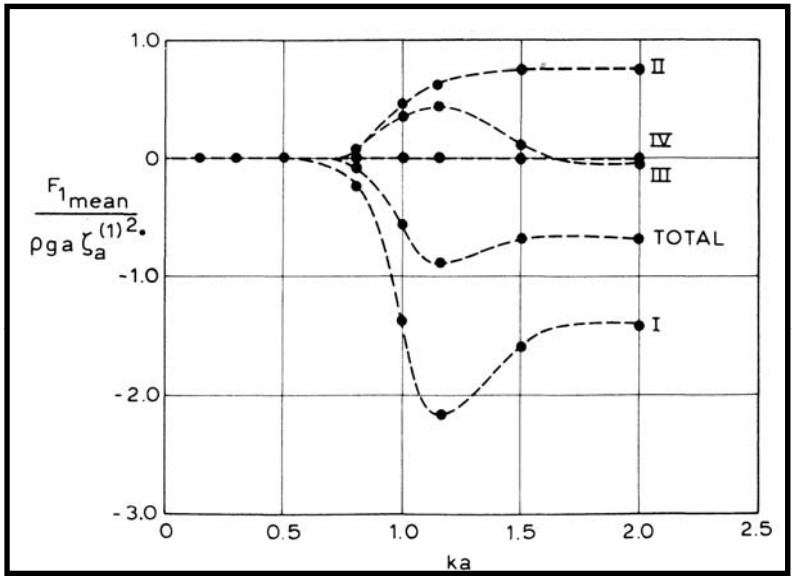
•Systematic analysis of second order wave loads reveals four components

I – Waterline integral of relative wave height squared

II – Surface integral of quadratic term of Bernoulli's equation

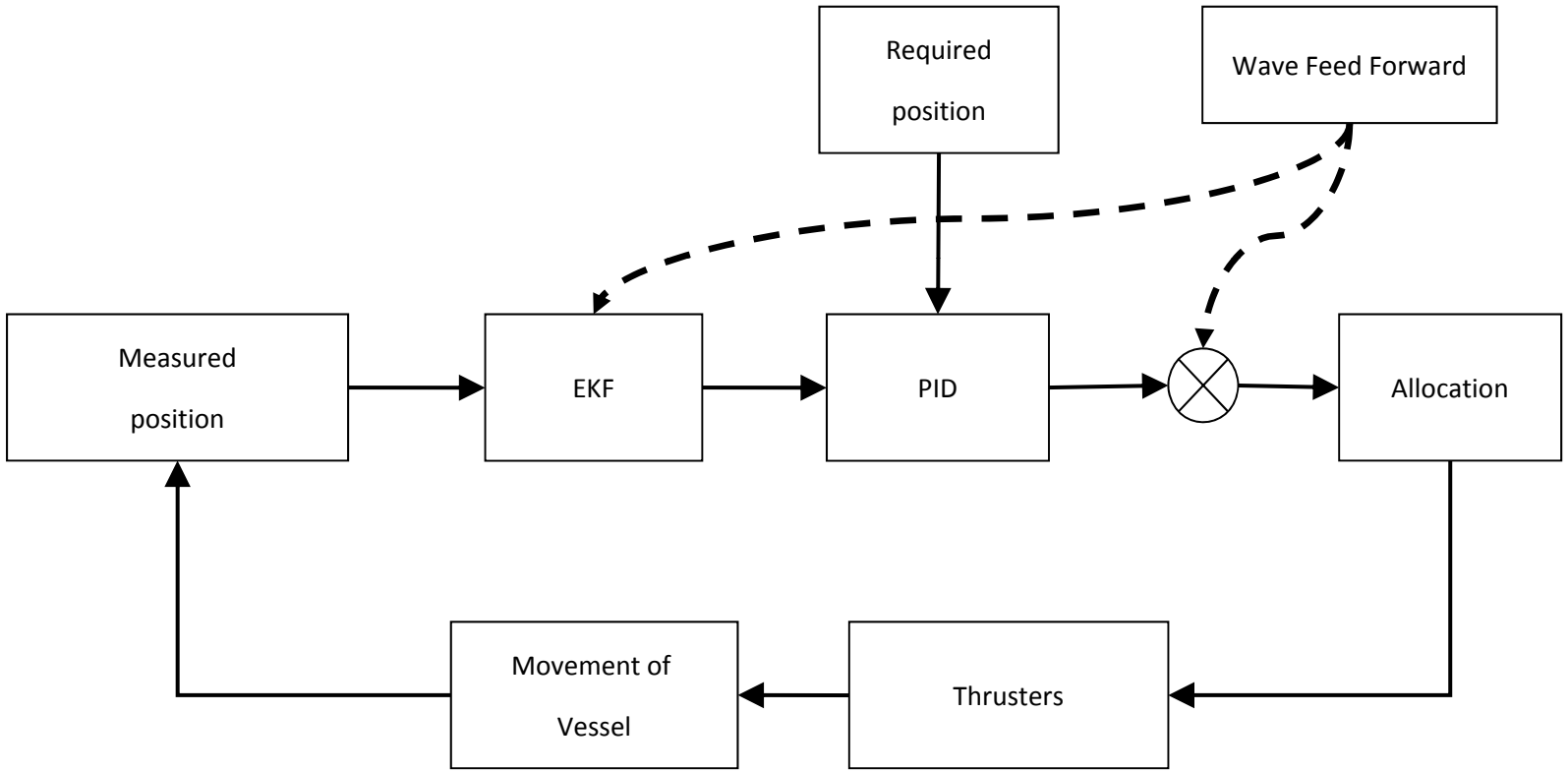
III – Product of the first order body translations and first order pressure

IV – Product of the first order body rotations and the first order forces



- A wave drift load estimation scheme can be based on the following observations:
  - Waterline integral is the dominant term
  - Waterline integral can be calculated in real time from relative waterline measurements
- *But*…..tuning "factors" are required to relate the waterline integral to total drift load.

Wave Feed Forward

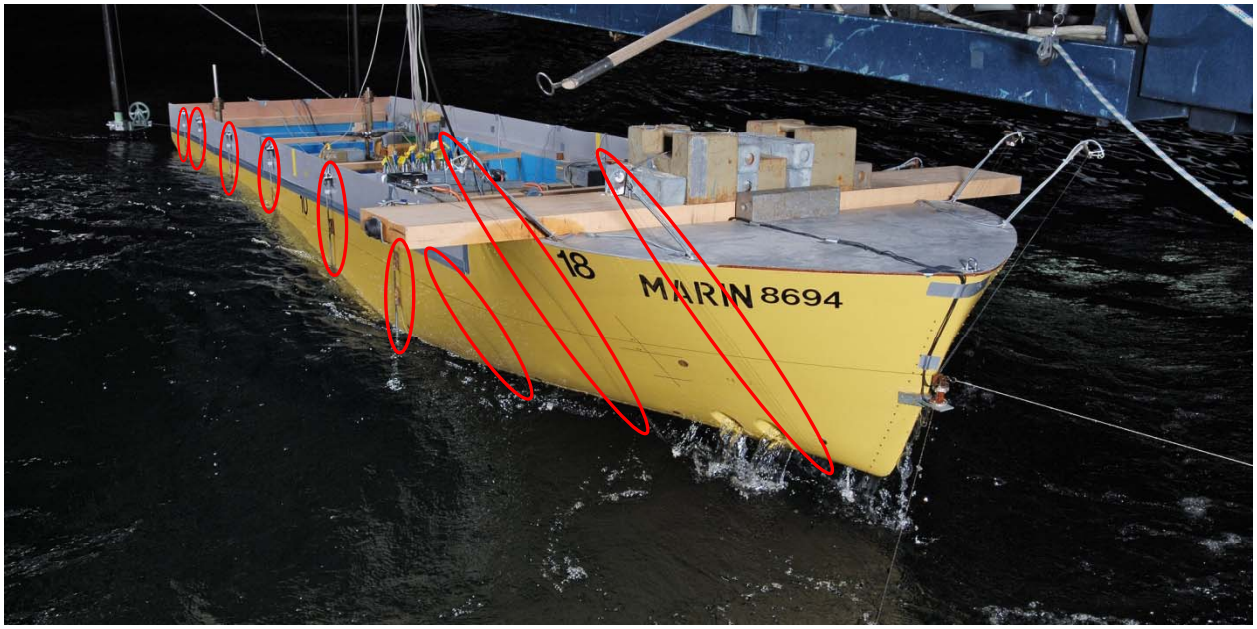


MARIN Tank Tests Aug 08, Nov 08 & June 09

Three test campaigns were conducted at MARIN to investigate WFF

- In addition to wave height sensors, pressure sensors and accelerometers were installed in the ships models

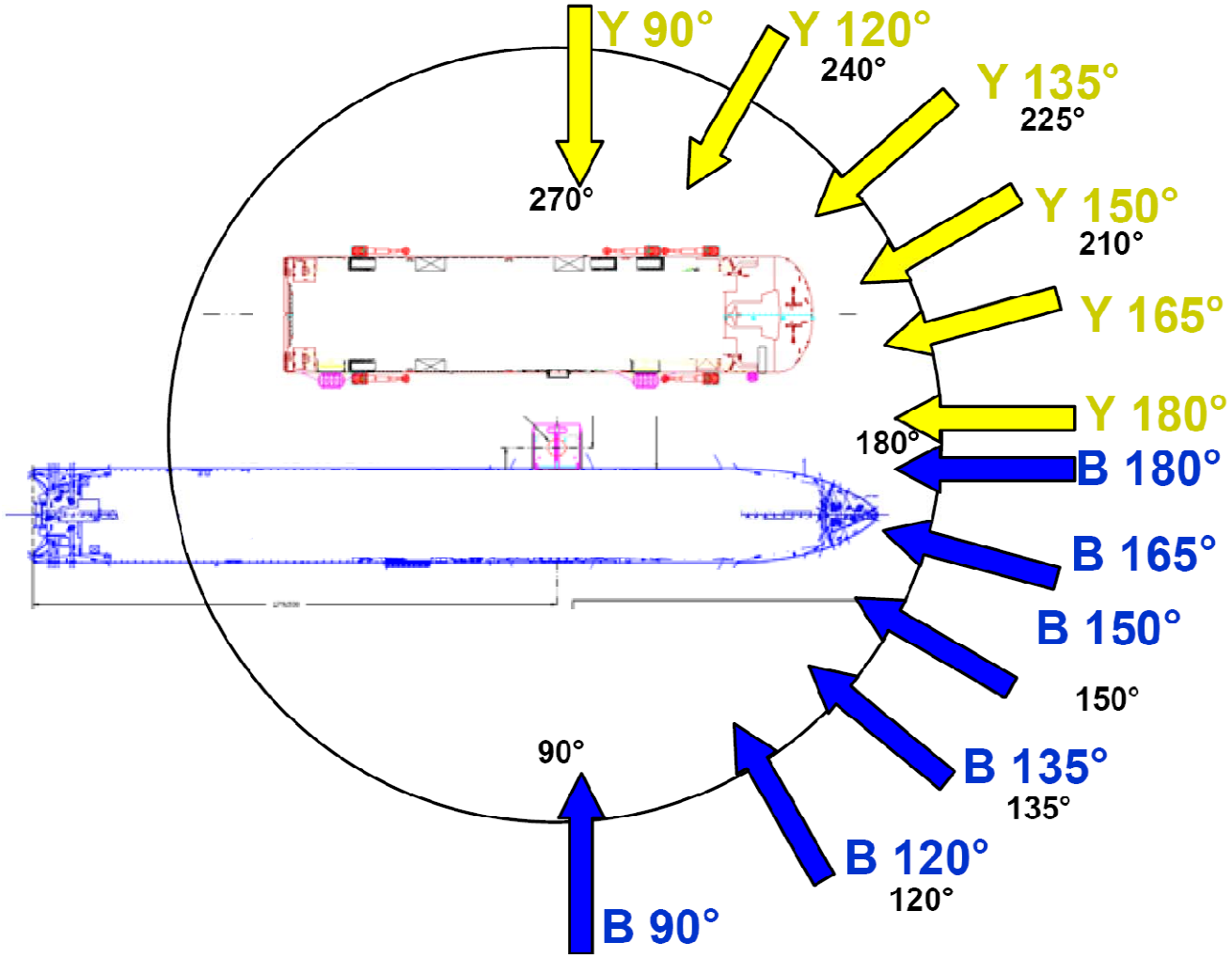
Test Set Up



20 wave height sensors (resistive probes), shown on the Transshelf, left (Aug and Nov 2008) and the MS3 right (June 2009)

Note the deep chine in the hull of the MS3, at the full scale 2010 VTAST sea trial, the draft of the MS3 will be half way up this chine

Wave Field Convention



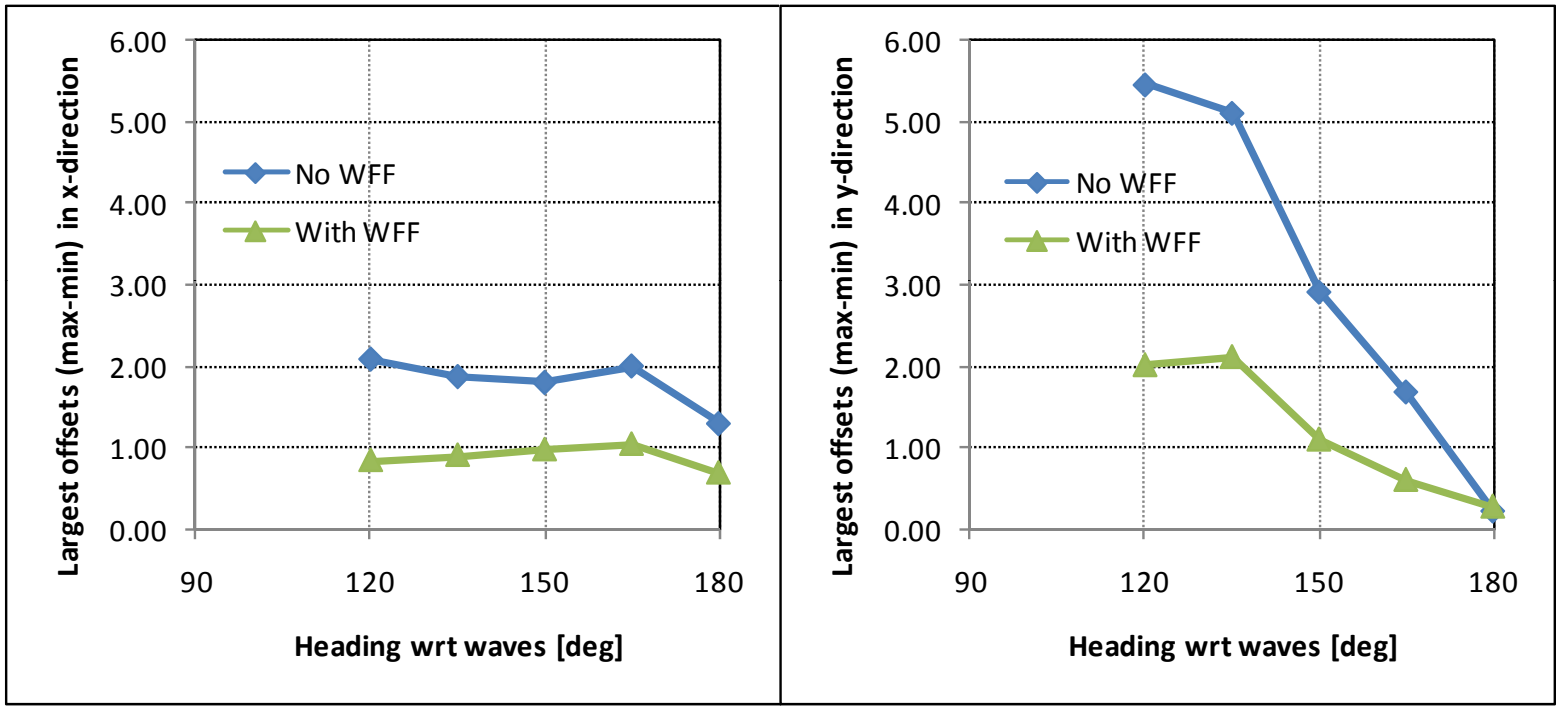
Single Ship Results, 0 Knots

WFF On/Off for a Single Ship, SS4, 0 knots, 100’ apart

Single Ship Results, 4 Knots

WFF On/Off for a Single Ship, SS4, 4 knots, 100’ apart

Single Ship Results



Single Ship SS4 test results show radical watch circle improvement in all conditions with Wave Feed Forward

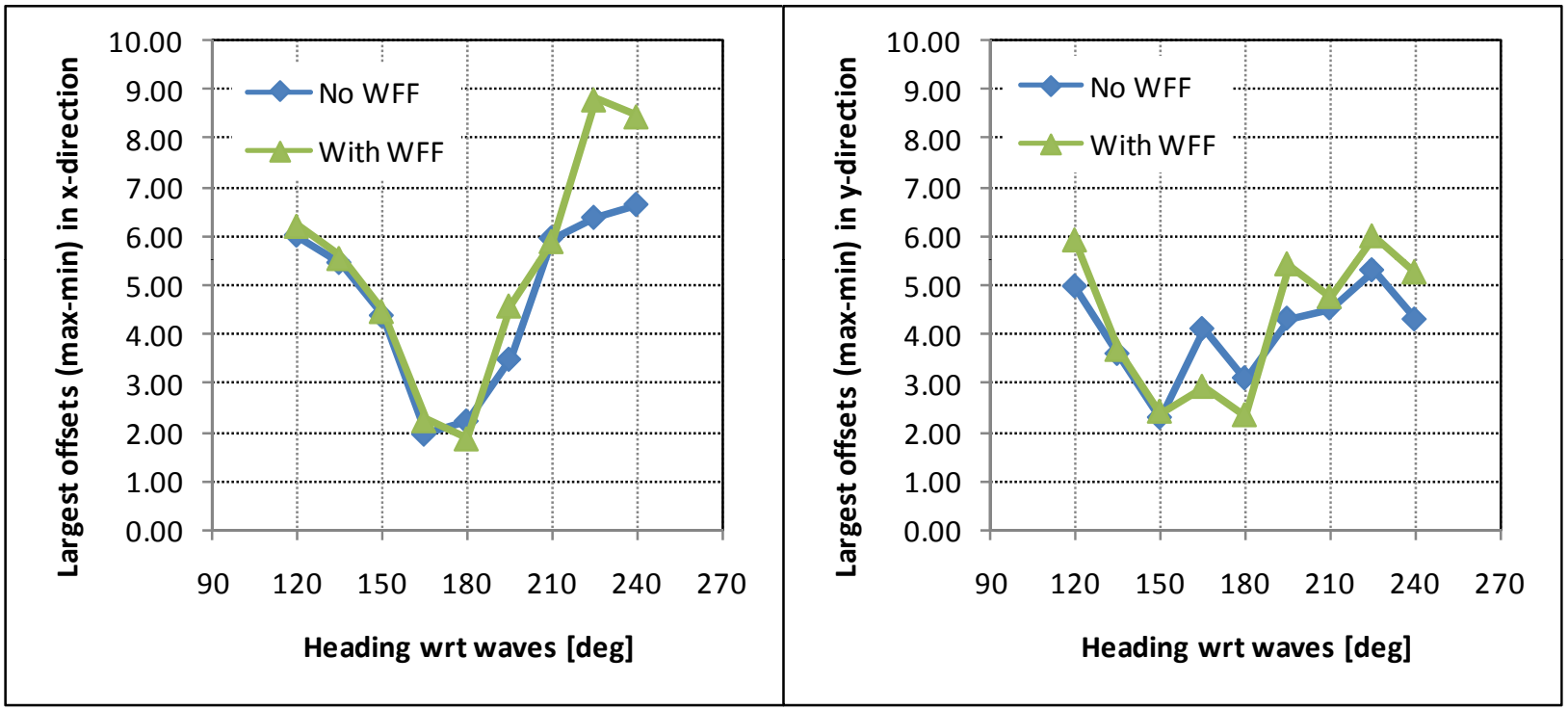
Two Ship Results, 0 Knots

WFF On/Off for Two Ships, SS4, 0 knots, 100’ apart

Two Ship Results, 4 Knots

WFF On/Off for Two Ships, SS4 4, knots, 100’ apart

Two Ship Results



Two Ship SS4 test results mixed, watch circle only improved at some headings with Wave Feed Forward

Tracking Issue for 2 Ships

WFF only solves half of the potential problem when tracking a second ship with DP

- At headings and in sea states where drift forces are significant, then WFF improves DP performance
- If however drift forces on the slave are low, but the master vessel experiences significant sway and yaw disturbance, then WFF doesn't necessarily improve DP performance.

Conclusions

The application of Pinkster's method of predicting second order wave drift forces has been successfully applied, in tank tests, to improve the position keeping performance of vessels at zero knots and ahead speeds

The addition of wave height sensors around a hull, and a simple calculation allowed a COTs-like DP controller to consistently half the watch circle of a single active vessel in SS3 and SS4

At some headings this improvement was also seen in the relative positioning, two ship, operational scenario of interest in seabasing. However two ship position keeping performance is also greatly affected by the "tracking issue", so further work required

PHASE 3 & 4

Our current and future challenge is to improve the position keeping performance of the MS3 when close alongside the LMSR and in contact with fenders, without the use of lines

- This mixed force and position regime, includes a capability for the MS3 to control the heading of the LMSR (dead ship) by using the DP to push the larger vessel around

- Some of the STLVAST capabilities will be demonstrated at a full scale sea trial in January of 2010.