Institute of High Performance Computing
A*STAR

GREEN AND SMART SHIPPING SEMINAR

13th February 2015

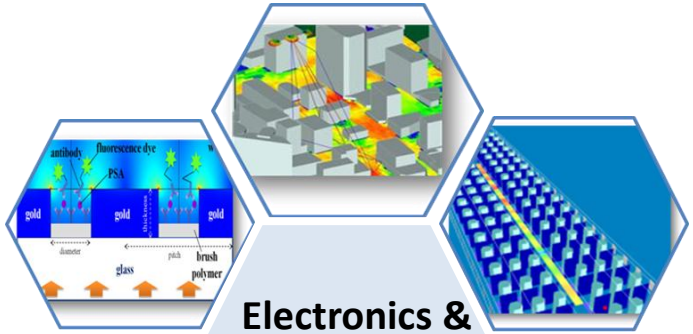
Institute of High Performance Computing (IHPC)

MODELING AND SIMULATION

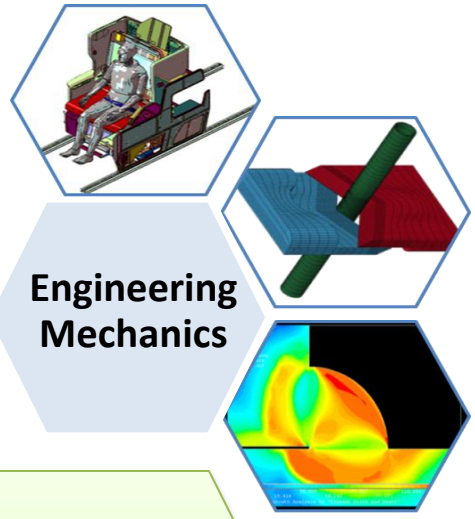
Enabling Green and Smart Shipping

KANG Chang-Wei

Computing Science



Electronics & Photonics



Engineering Mechanics

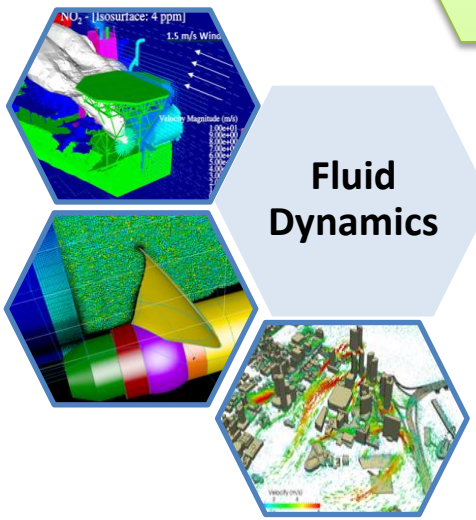
Institute of High Performance Computing
A*STAR

Vision:

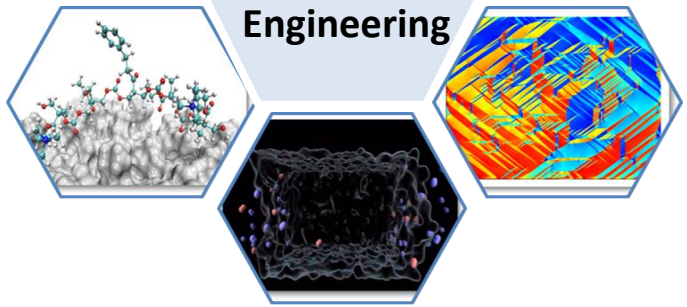
To provide leadership in the use of high performance computing as a strategic resource for scientific inquiry and industry developments.

Mission:

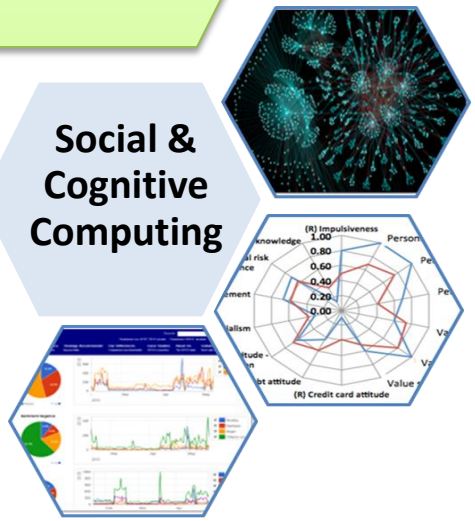
To advance science and technology, and develop leading edge applications, through high performance computing and computational science.



Fluid Dynamics



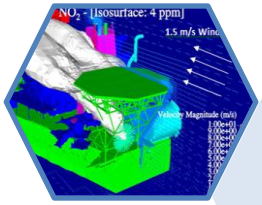
Material Science & Engineering

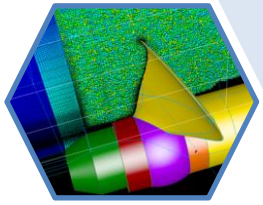


Social & Cognitive Computing

Part 1:
IHPC's Capabilities for Green Shipping

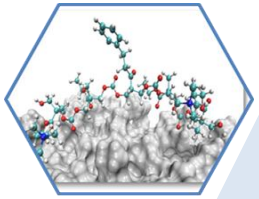
Institute of High Performance Computing (IHPC)

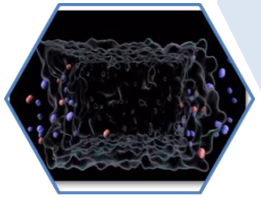




Fluid Dynamics

Study dynamics of fluid/heat flow and their interactions





Material Science & Engineering

Advance Materials/Chemical Science by Computation

Why Green Shipping is important ?

International shipping transports about 90% of global trade to people and communities all over the world.

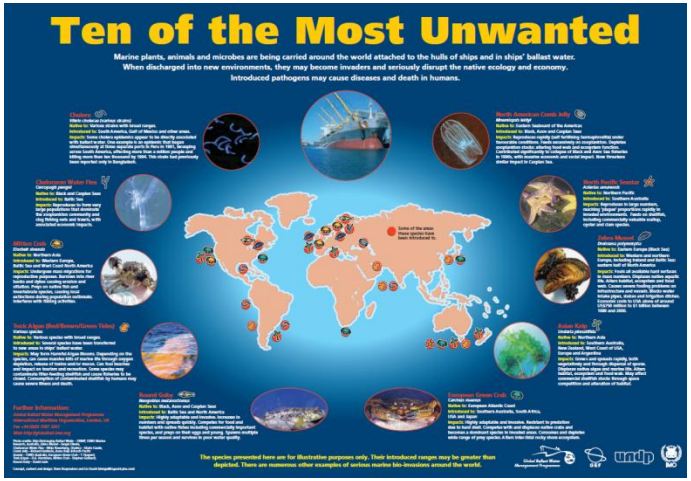
Atmospheric Impact

Shipping industry accounts for 3% of global greenhouse gas emissions.

http://articles.maritimepropulsion.com

Oceanic Impact

Approximately 3-7 billion tonnes of ballast water is transferred internationally every year. The annual damages related to invasive species was estimated to cost $120 billion for the United States alone.



http://globallast.imo.org/

Atmospheric Environment

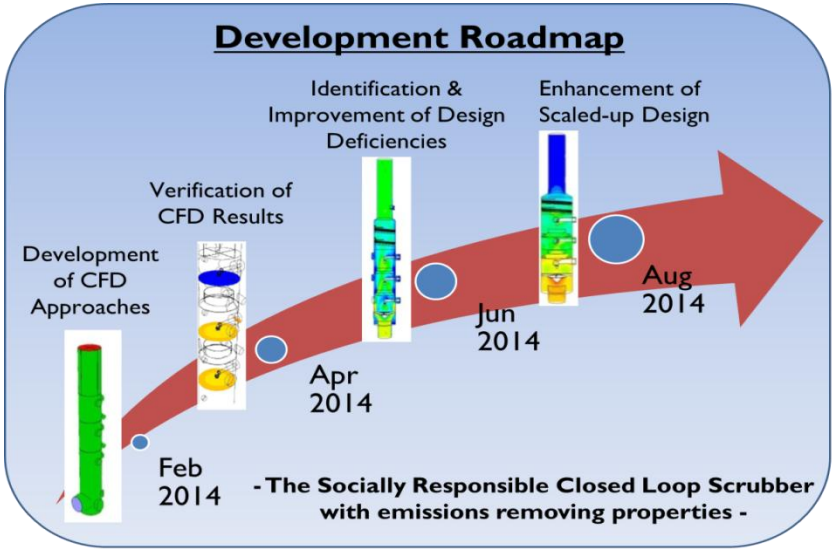
Highlight: cSOx Scrubber Tower

Technology Overview

- cSOx System is a revolutionary Exhaust Gas Cleaning System (EGCS), whereby the washwater (sea water) property is enhanced for SO_2 emission abatement.
- cSOx emission abatement process involves removal of SO_2 and a small amount of CO_2.
- Emission abatement performance of cSOx system complies with the SO_2 (ppm) / CO_2 (% v/v) emission ratio requirement as per MEPC.184(59), in which the gas emission ratio must not exceed 4.3.

Methodology

- Volume of Fluid (VOF) is adopted to trace the free boundaries of liquid jet spraying out from the nozzle. Accurate prediction of pressure drop is achieved, as compared to site measurement.



Quotes

"..it is a better and more accurate simulation result than other simulation programs we had used before.. It gives us good predictable results."

- Chew Hwee Hong, Managing Director, Ecospec Marine Technology Pte Ltd

"..it gives us greater confidence in our design, and surfaces the problem areas to allow us to refine our design on the drawing board prior fabrication..'

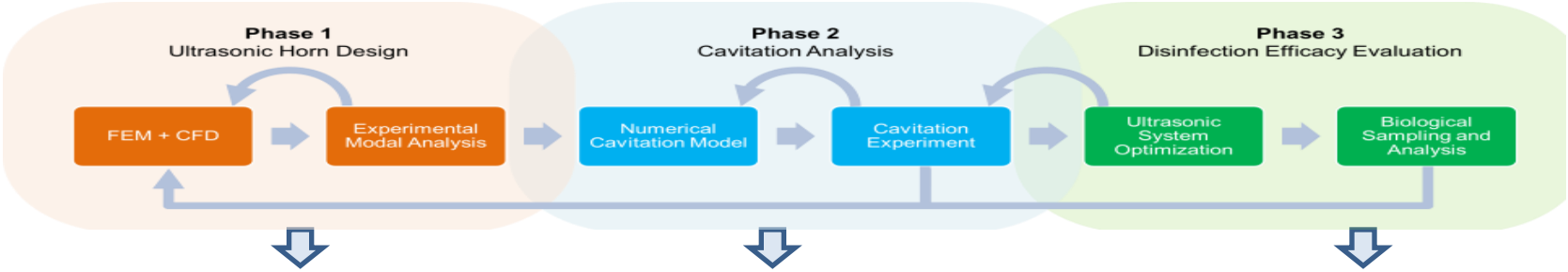
- Simon Kuik, General Manager, Technology Development & Solutions Sembawang Shipyard Pte Ltd

Oceanic Environment

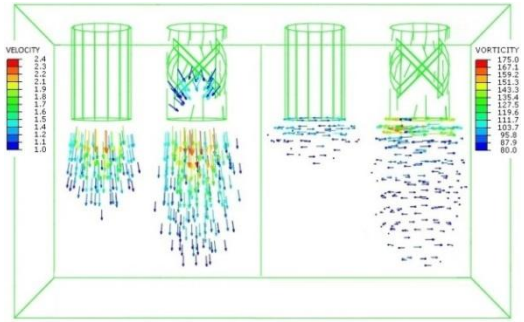
Highlight: Ultrasonic Ballast Water Treatment

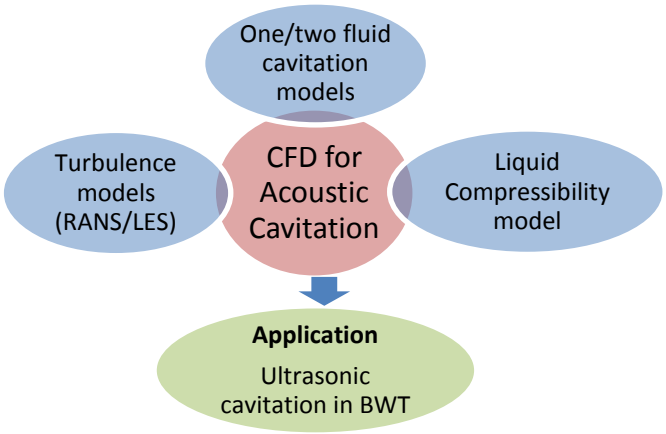
Motivation

- Ultraviolet (UV) radiation is the commonly applied technique in non-chemical ballast water treatment
- Limitations such as high power consumption, dependence on UV transmittance (UVT) of the water, and dependence on water temperature
- A properly designed ultrasonic system is adaptable to most water conditions, not affected by water quality, and has relatively low power consumption



Velocity Vorticity





	Power Output (W)	Exposure Time (s)	Dead (Sample of 20)
Barbell horn	105	1	13
		2	19
Radial Horn	102	1	All
		2	All

Oceanic Environment

Highlight: Coating for Corrosion Prevention

Motivation

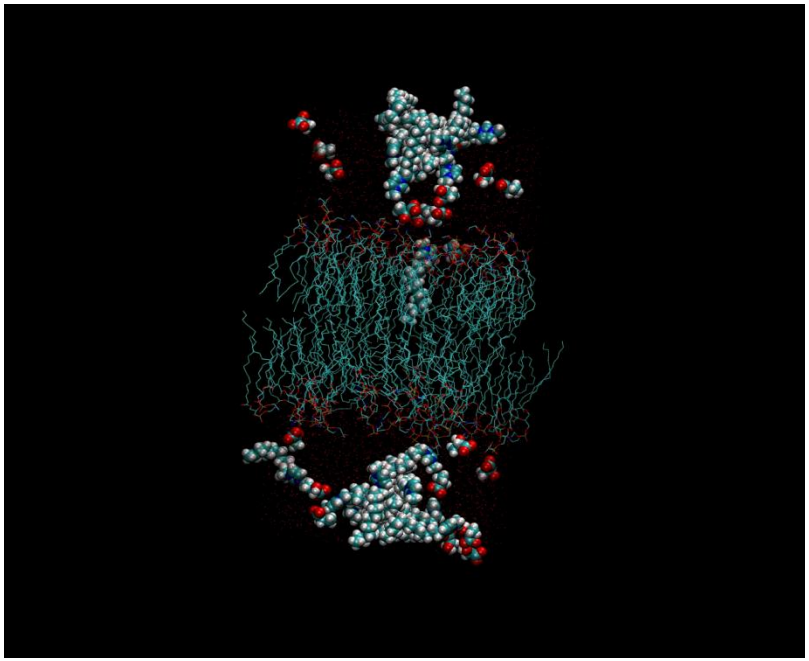
- Coatings are often used to improve surface properties of the substrate, such as appearance, adhesion, wetability, corrosion resistance, wear resistance and scratch resistance etc
- Diffusivity is one of important properties.

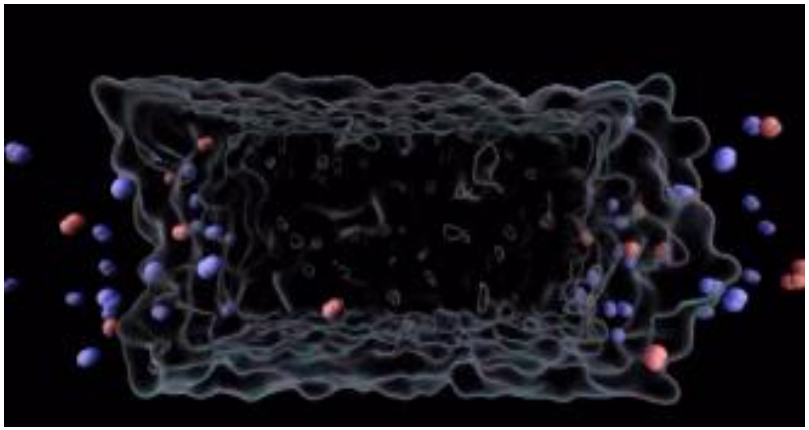
Method

- Molecular dynamics simulation, first-principles calculation, Monte Carlo simulation, materials informatics and multi-scale simulation

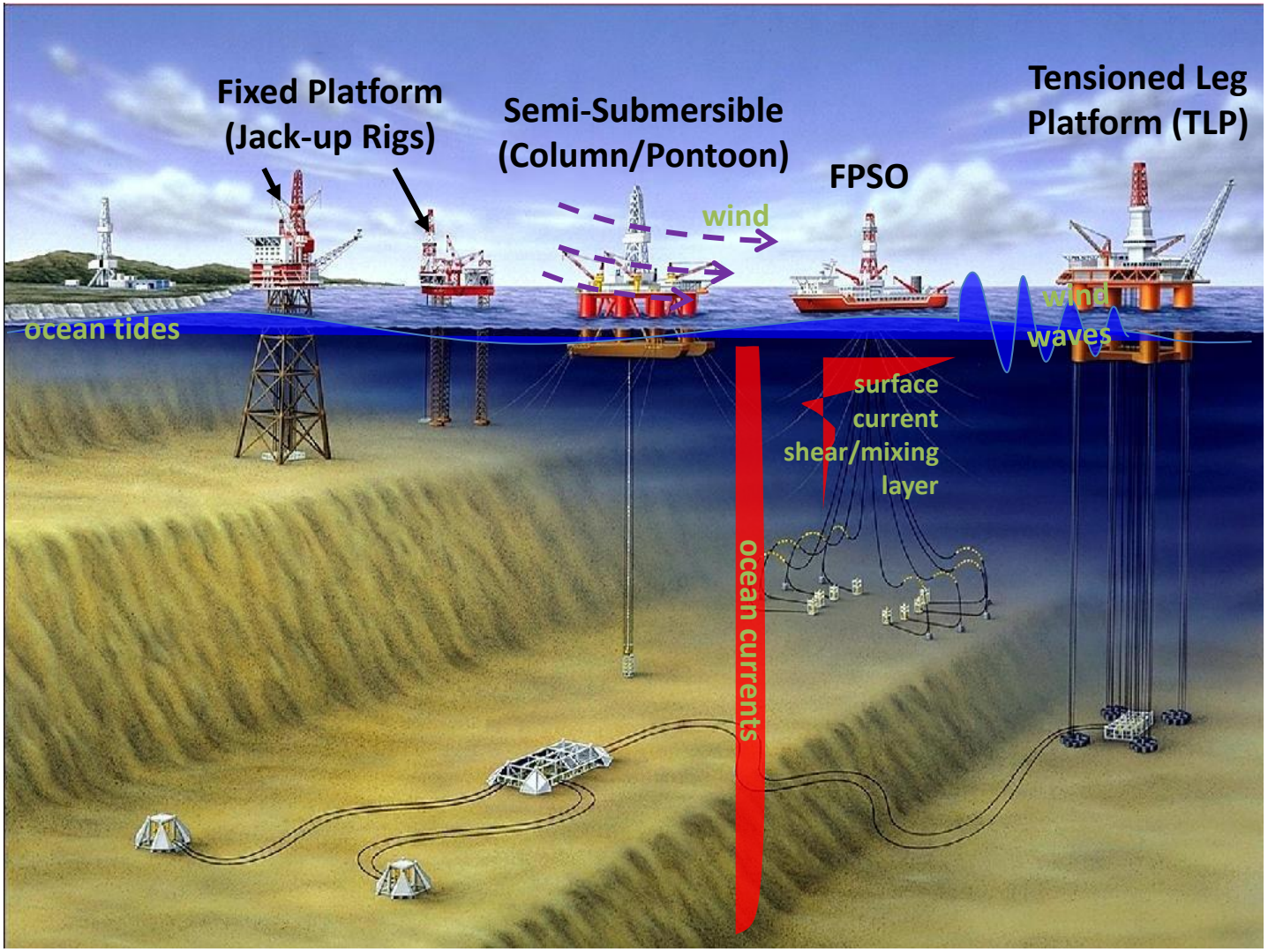
Application

- Coating design
- Barrier/diffusivity property
- Anti-bacteria
- Self-cleaning/anti-contamination





Why Green Shipping is important?



CFD as a Virtual Lab

Highlight: Numerical Framework for Wave Dynamics and Current

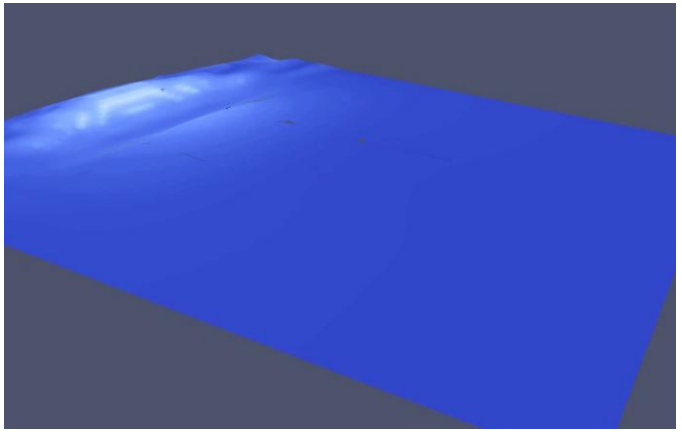
Motivation

- Offshore engineering moves to deeper sea & harsher environment. Traditional tools and model basin tests reach limits.
- Off-the-shelf CFD packages are not generally developed for offshore engineering problems.

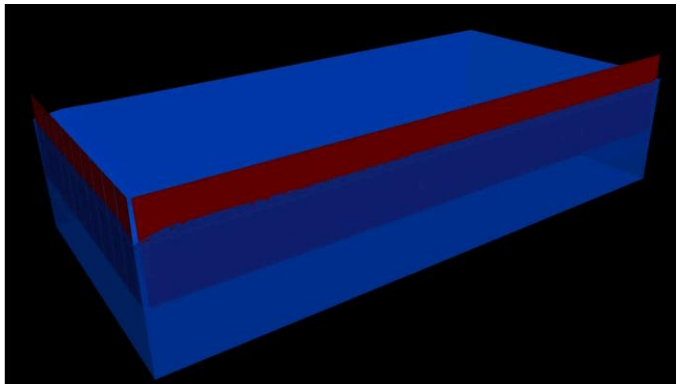
Approach

- Seek to develop and integrate a set of CFD tools for offshore applications of complex hydrodynamic problem.
- Tools validations on offshore platform in separate stages.
- Offshore Platforms and Cases: Floating Barge, Semi-Sub, Tanker.
- Studies: Rigid Body Motion, Vortex-Induced Motion of Floaters.

Generating Waves using Wave Theory

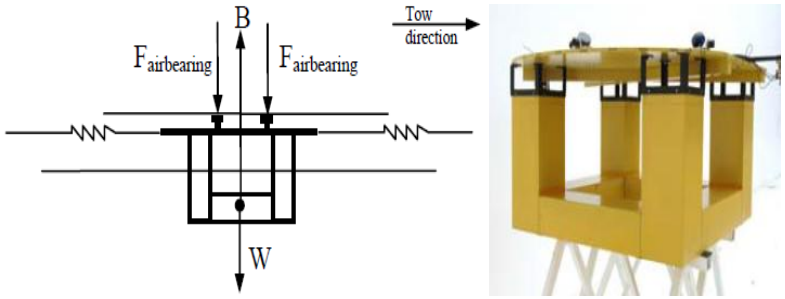


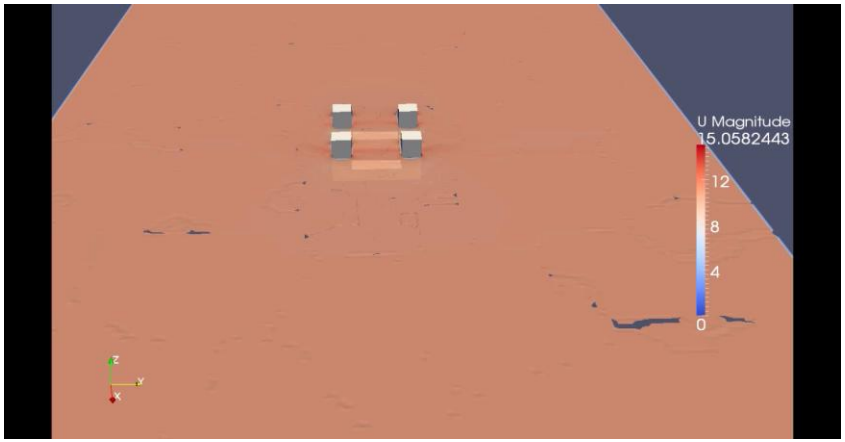
Generating Waves using Moving Paddles



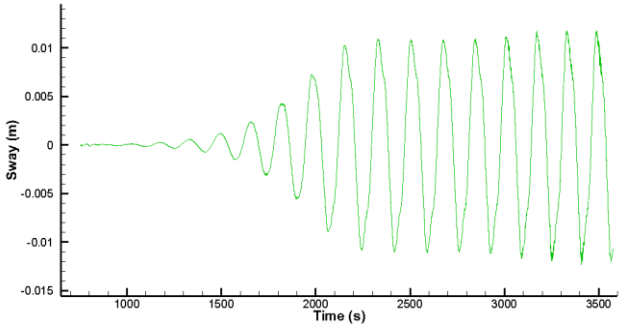
CFD as a Virtual Lab

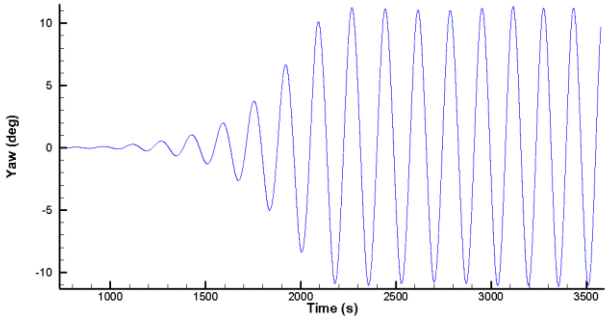
Highlight: Vortex Induced Motion (VIM)





I: Deep Draft Semi Submersible				
Mass t	Displacement t	Mass Ratio	Draft m	Column height m
44000	53000	0.83	35	24.5





Numerical Method

- Time domain Navier-Stokes based incompressible solvers using unstructured meshes
- Moving (morphing) mesh based 6DoFs model
- Stable algorithm for long period (>3k second) simulations
- Accurate schemes to predict VIM
- Parallel computing on large scale high performance clusters (> 20K CPU cores)

CFD as a Virtual Lab

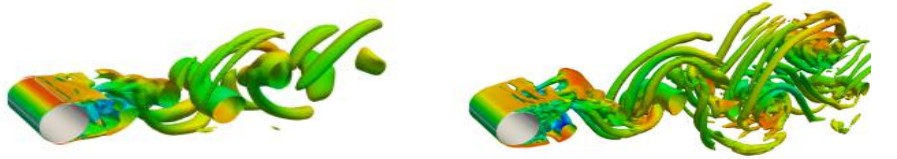
Highlight: Vortex Induced Vibration (VIV)

Motivation

- Vortex induced vibrations (VIV) are highly nonlinear hydrodynamics phenomena.
- These vortices, in turns change hydrodynamic loading conditions on the structures.

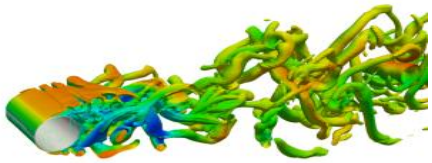
Approach

- Conduct numerical experiments to investigate effects of VIV on offshore structures
- Explore mechanisms to suppress VIV effects on structure reliabilities.

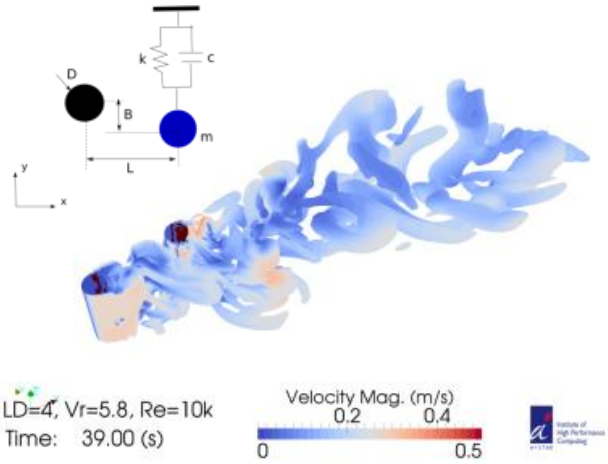


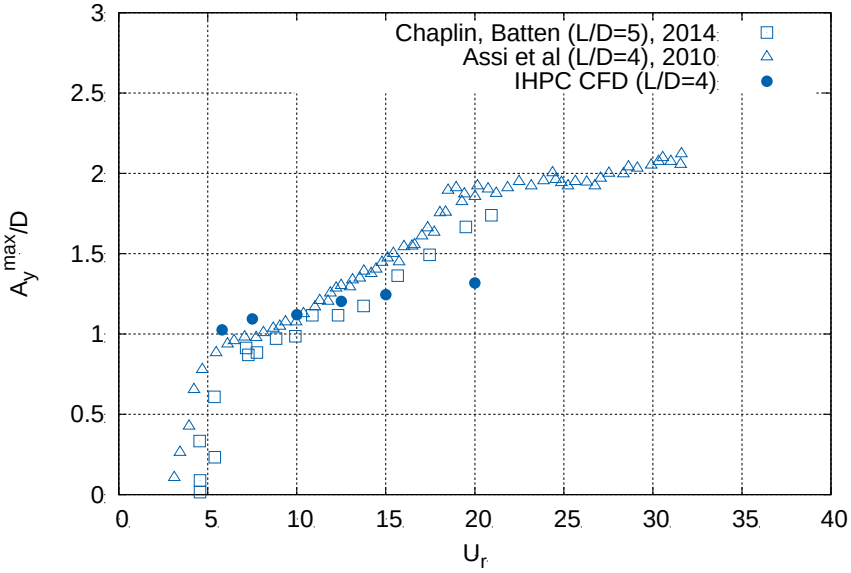
RANS KKL, **Re=6.4e4**, Q=1

LES, **Re=6.4e4**, Q=1



Hybrid, **Re=6.4e4**, Q=1





CFD as a Virtual Lab

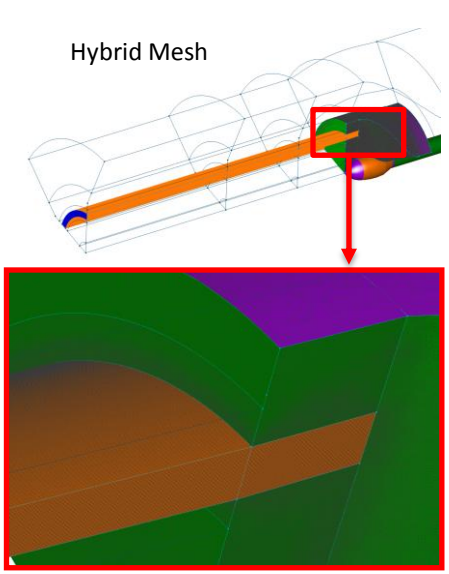
Highlight: Propeller Vortex Persistence

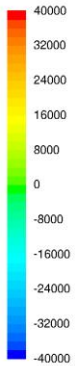
Focus

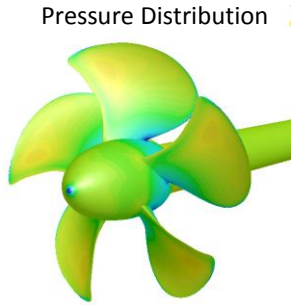
- Generate CFD-based propeller vortex persistence model
- Validate at model scale

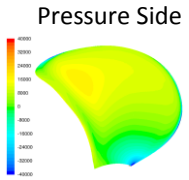
Approach

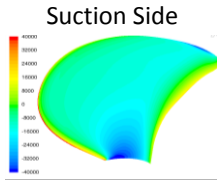
- Modeling of tip vortex
- Vortex persistence modeling methods (Local Mesh Refinement and Vortices Confinement Method)



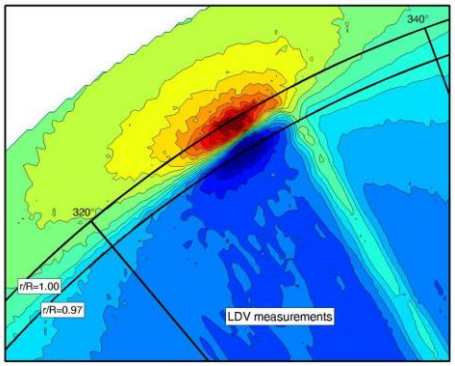




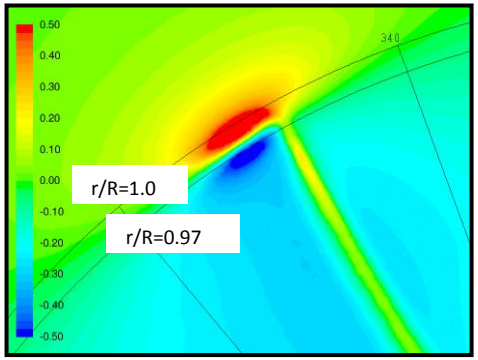


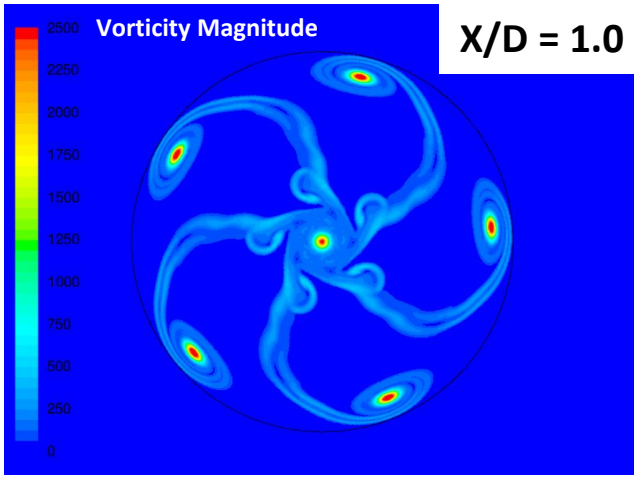


Experiment



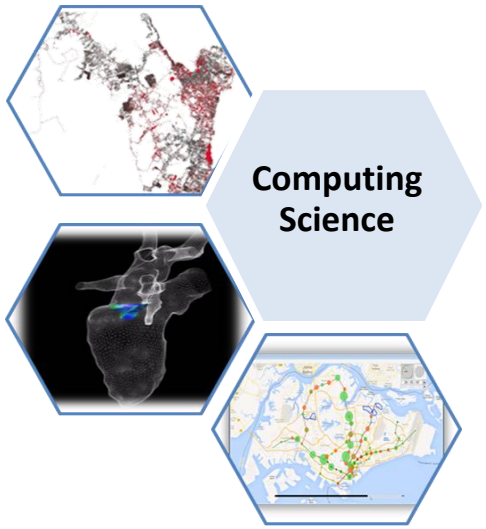
CFD





Part 2:
IHPC's Capabilities for Smart Shipping

Institute of High Performance Computing (IHPC)



Making computing more efficient, insightful & intelligent

Why Smart Shipping is important?

*Vessel performance monitoring and optimization solution ClassNK-NAPA GREEN

The software solution, which can be used on all major vessel types, combines advanced monitoring and analysis systems to optimize trim, speed and voyage routing among other factors, with a unique, self-learning Dynamic Performance Model which can estimate a vessel's performance in actual vessel operating conditions with an accuracy of as much as 99.6%. These have produced verified fuel savings of between 4-6% and emissions.

This in turn paved the way for the smart ship.

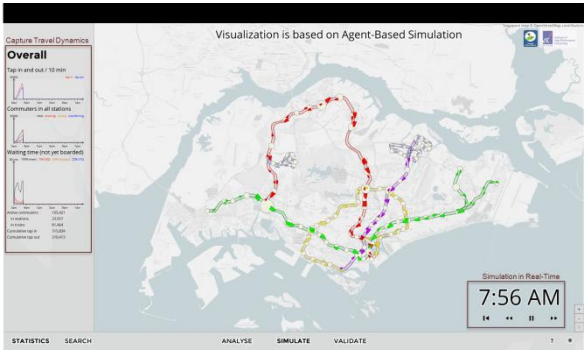
Smart ship enables better informed decision making through the use of advanced analytics.

**Source: http://www.napa.fi/News/Press-Releases/ClassNK-NAPA-GREEN-named-top-maritime-IT-Solution-at-IBJ-Awards2*

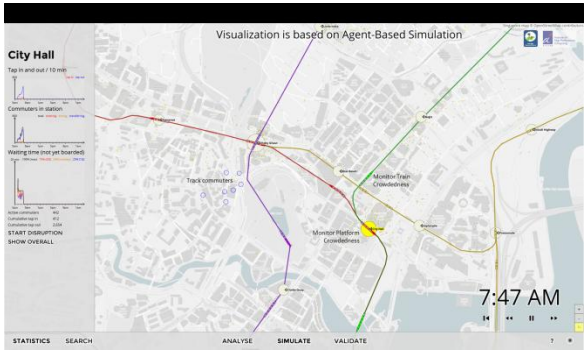
Complex System

Highlight: Smart Transportation

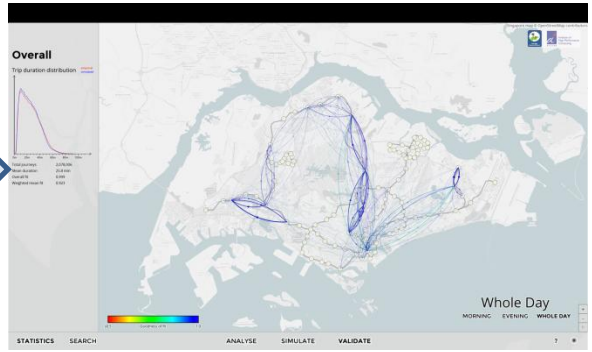
Development



Reconstruct actual dynamics of the Singapore Mass Rail Transit System in Real-Time.

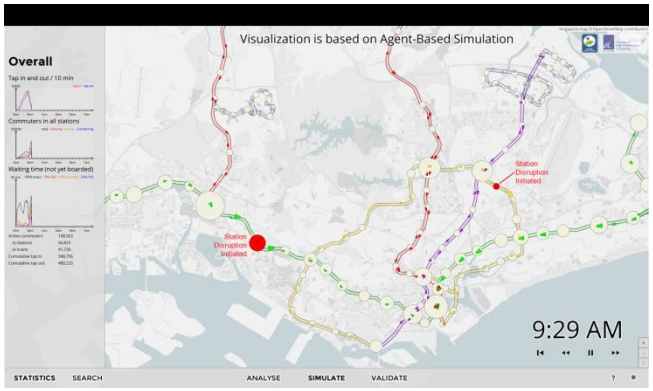


Track commuters at the individual scale. Monitor individual station platform and train crowdedness.

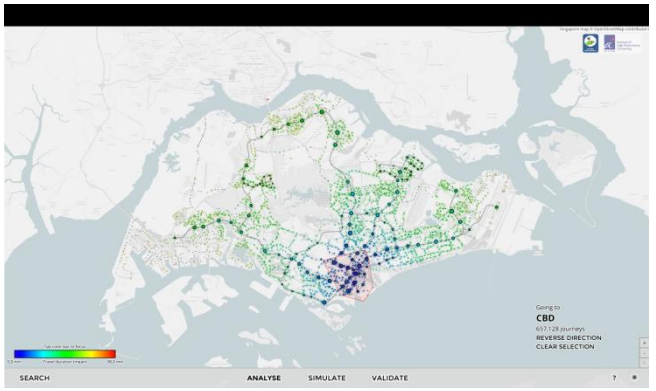


Validate simulation results with empirical ticketing data.

Application



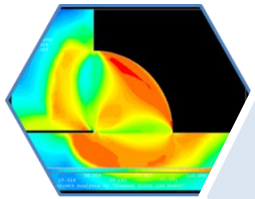
Evaluate over-all effects of various hypothetical scenarios such as station disruptions instantaneously.



Analyse and Visualise Zone-to-Zone, Origin-Destination Travel Statistics.

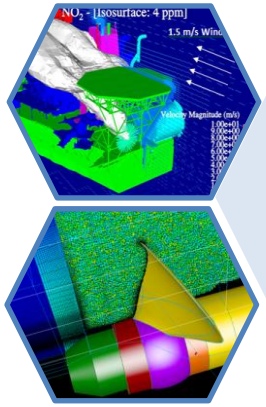
Part 3:
IHPC & ClassNK Collaborations (Past & Future)

Institute of High Performance Computing (IHPC)



Engineering Mechanics

Design and Analysis of Engineering Systems



Fluid Dynamics

Study dynamics of fluid/heat flow and their interactions

Past Collaboration

Highlight: Fatigue Consortium

Background & Motivation

- Current empirical approaches to fatigue assessment in the maritime industry are not reliable - limiting use of new materials and leading to over-designed structures.

Methodology

- Developed a fatigue analysis technique which incorporates state-of-the-art methodologies & numerical techniques
- Technique accounts for:
  - Crack propagation path
  - Loading sequence
  - Mean and residual stress

Results & Significance/Impact

- Technique has gained the interest of the maritime industry and a fatigue consortium of classification societies has been formed to advance research in this area.

This collaboration was carried out with the support of ClassNK as part of the ClassNK Joint R&D for Industry Program

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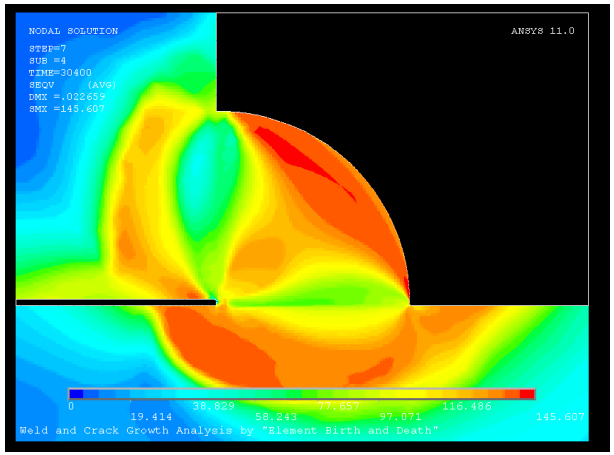
ClassNK R&D PROJECT

Consortium members



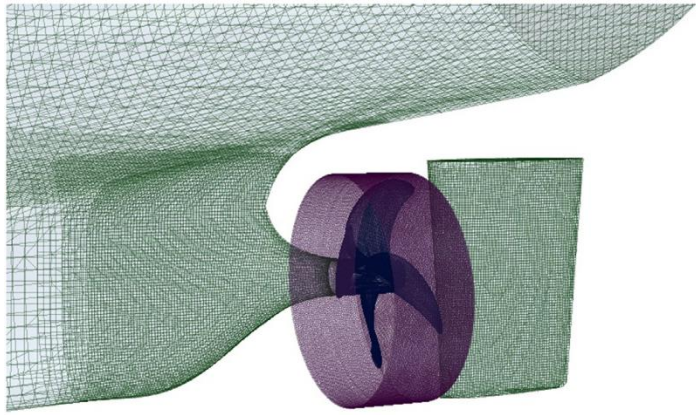
Development of a First Principle Based Fatigue Analysis Technique for FPSO Structures

An Example of Future Collaboration

Highlight: Propeller Cavitation Induced Noise

*The International Maritime Organization (IMO) recently adopted guidelines to reduce underwater noise from commercial ships. The new guidelines recognize that shipping noise can have short-term and long-term impacts on marine life and provide guidance for designing quieter ships and for reducing noise from existing ships, especially from propeller cavitation.

#1. Masking: the radiated noise from the vessel, chiefly the propeller and machinery, can hide biologically important noises such as communication, prey or predator noises, and sounds used for orientation.
#2. Avoidance, where the occurrence of a sound or continual noise causes the marine wildlife to leave or avoid a certain area. This becomes problematic if the area has biological significance, as a feeding, breeding or nursing ground, or is a traditional migration route.



Source:
**http://sea-inc.net/2014/04/16/imo-adopts-guidelines-to-reduce-underwater-noise-from-commercial-ships/*
#Paula et al., 2013, A Study of Numerical Ship Underwater Noise Prediction, Ocean Engineering 66, pp. 113–120

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