A rapid model for the assessment of ship hard grounding

Marine Technology GALA

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30 November, 2022

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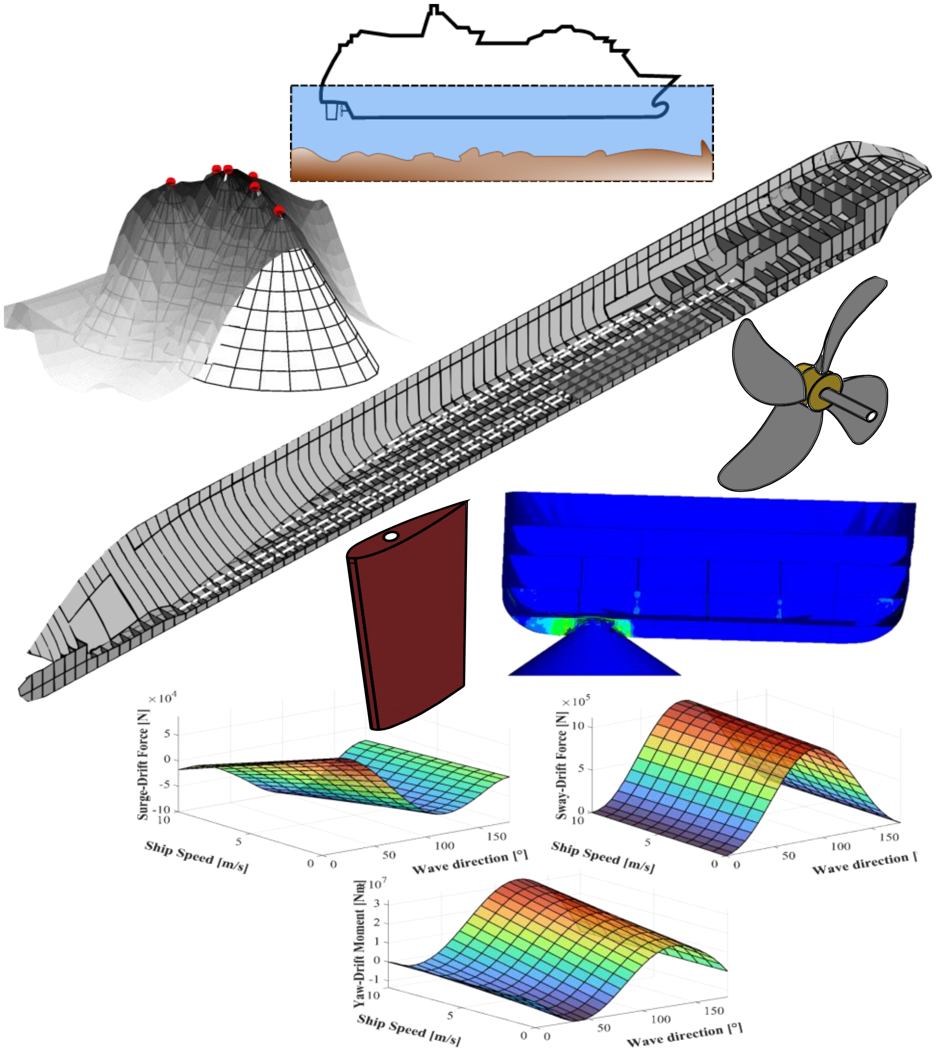
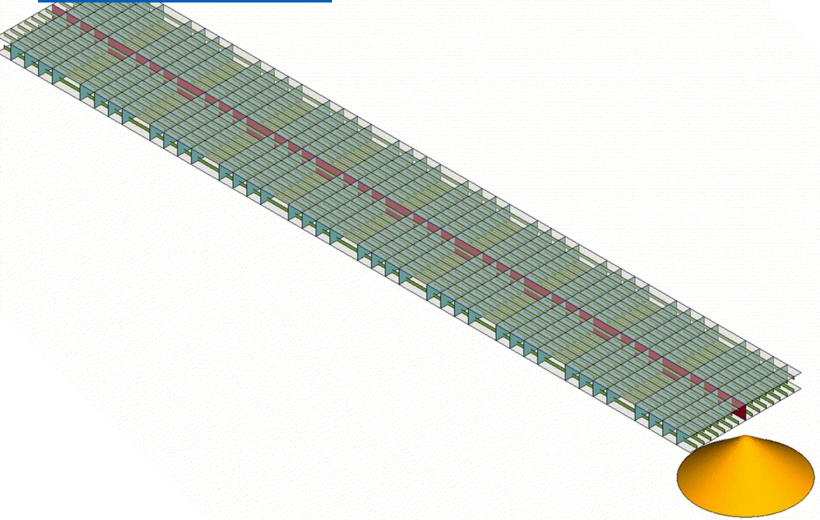
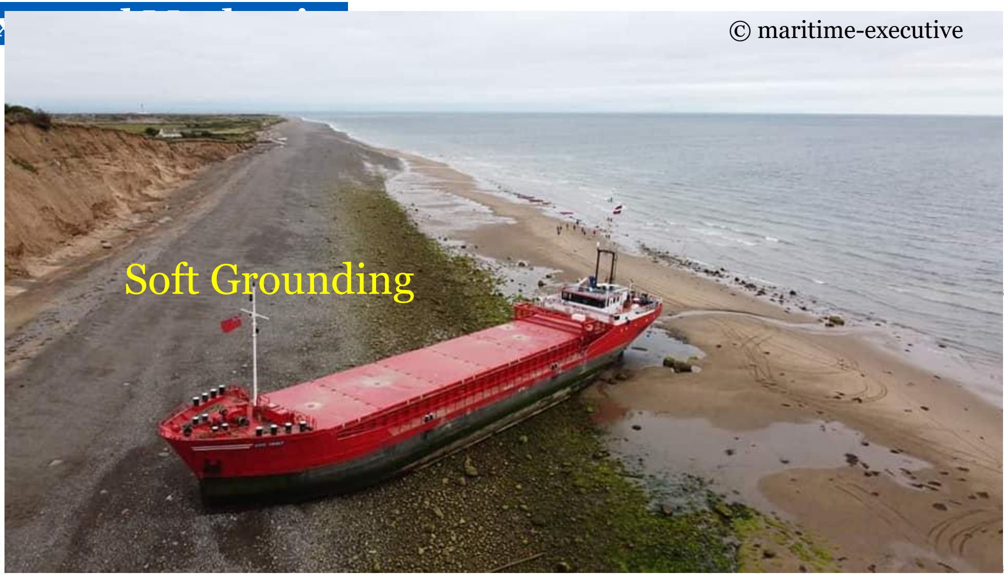


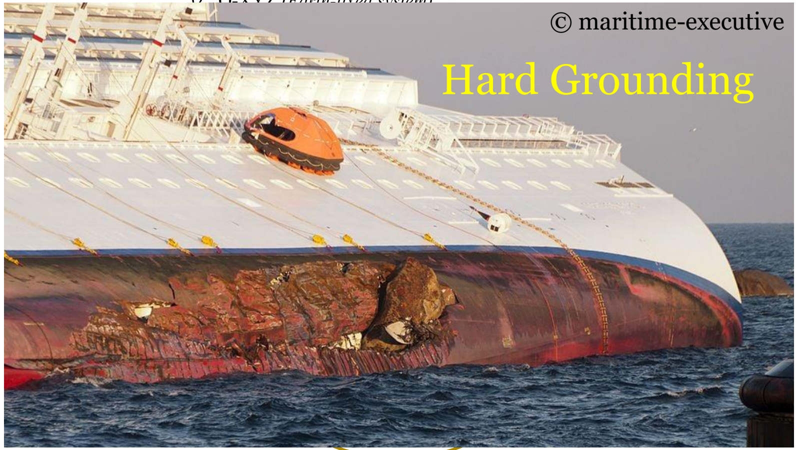
Overview

- What is ship grounding?
- Key Terminologies

Internal Mechanics







Content

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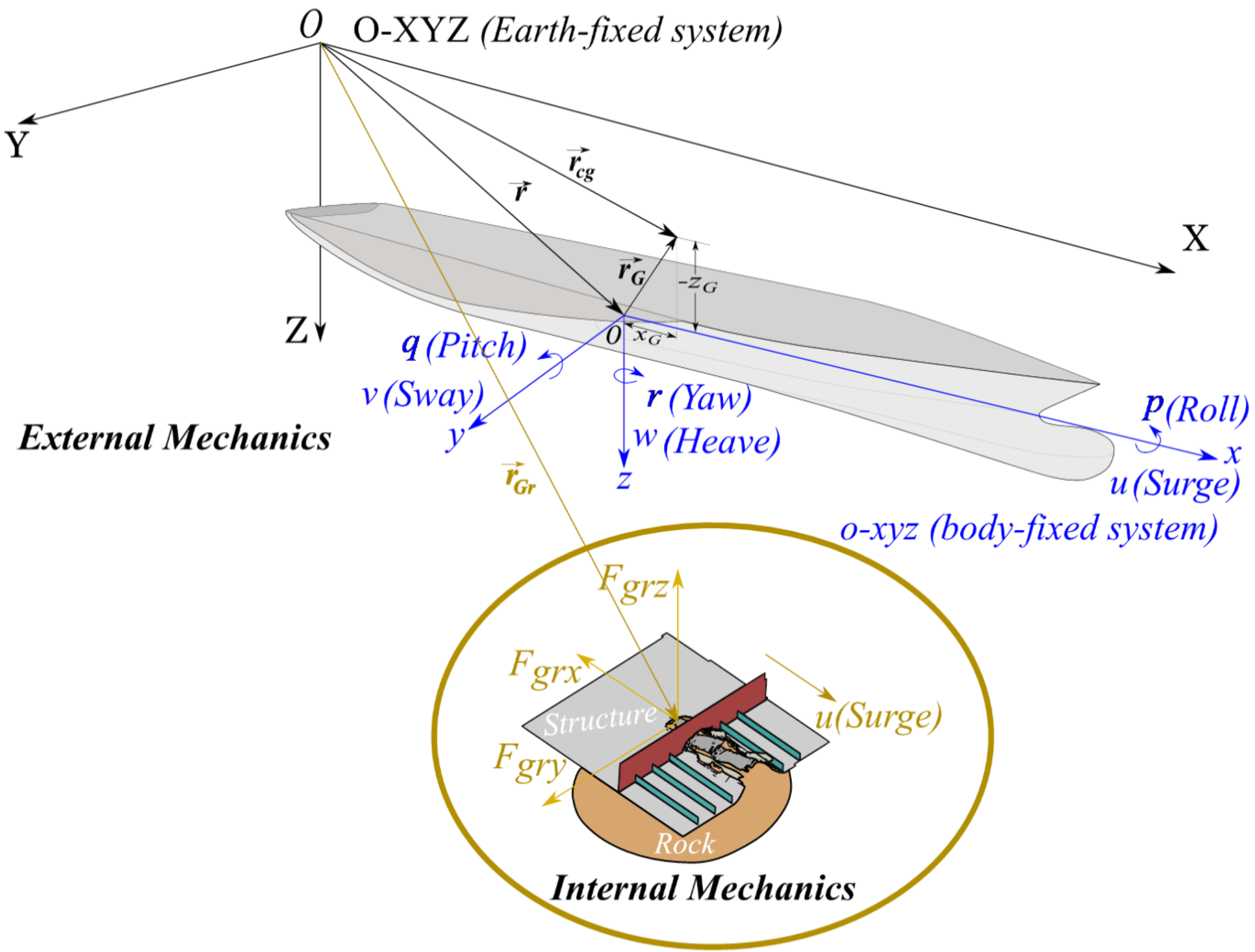
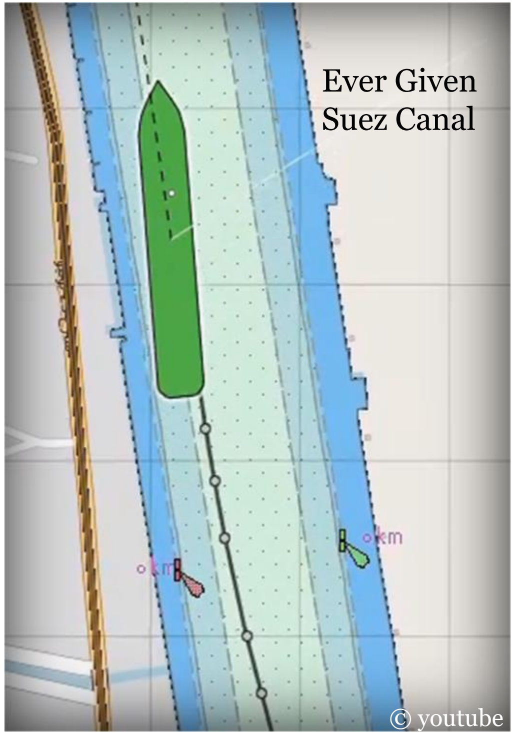
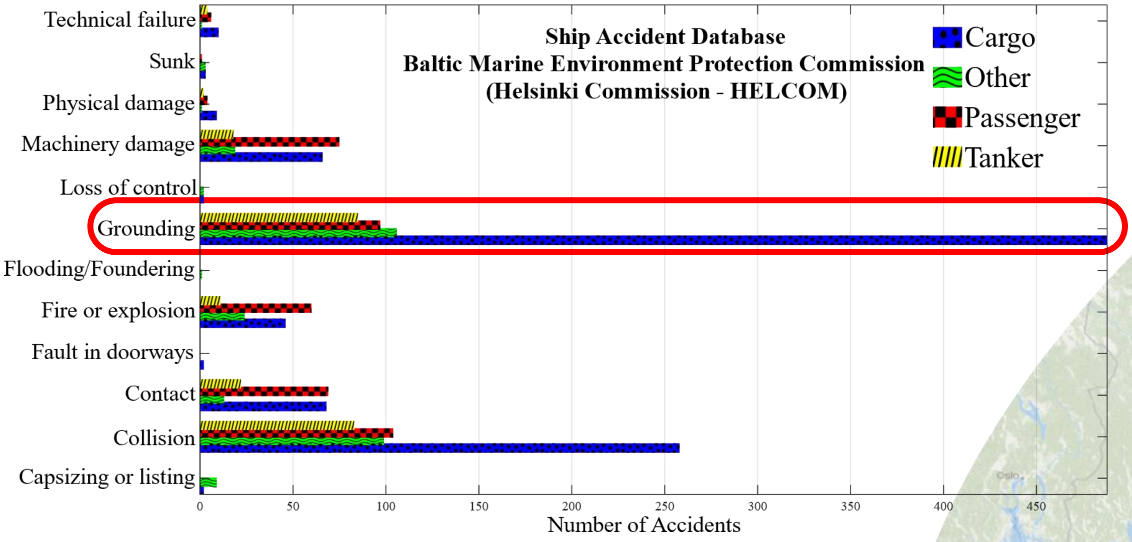
- ❖ Research challenges
- ❖ Aims
- ❖ Methodology
- ❖ Summary of results
- ❖ Conclusion
- ❖ Applications

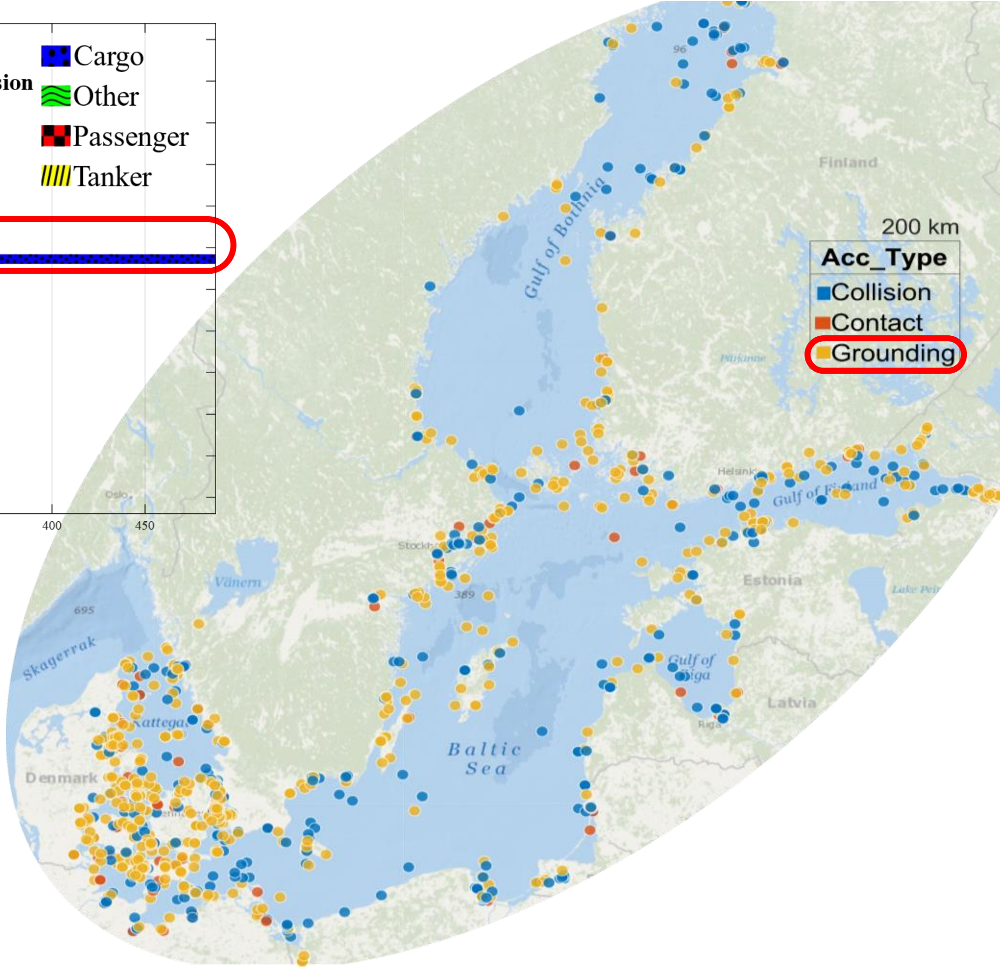


Background

- ❖ Ship Grounding can cause
  - ❑ Contamination of marine habitats,
  - ❑ Disruption of traffic flow,
  - ❑ Serious ship damages, and
  - ❑ Loss of human life
- ❖ Grounding accidents pose significant safety risks
- ❖ Grounding accidents are frequent while navigating in confined and shallow waters.





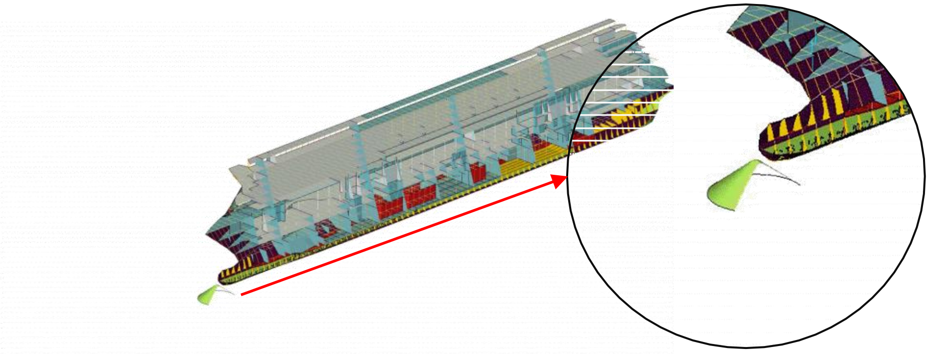


Accident statistics in Baltic Sea from 2000-2018, data from (HELCOM – Helsinki Commission, 2021)

- ❖ Ship accidents tend to persist despite regulatory advancements.
- ❖ Risks associated with accidental events should be reduced to improve maritime safety
- ❖ To mitigate grounding risks and enhance ship safety rapid time-domain multiphysics models are required

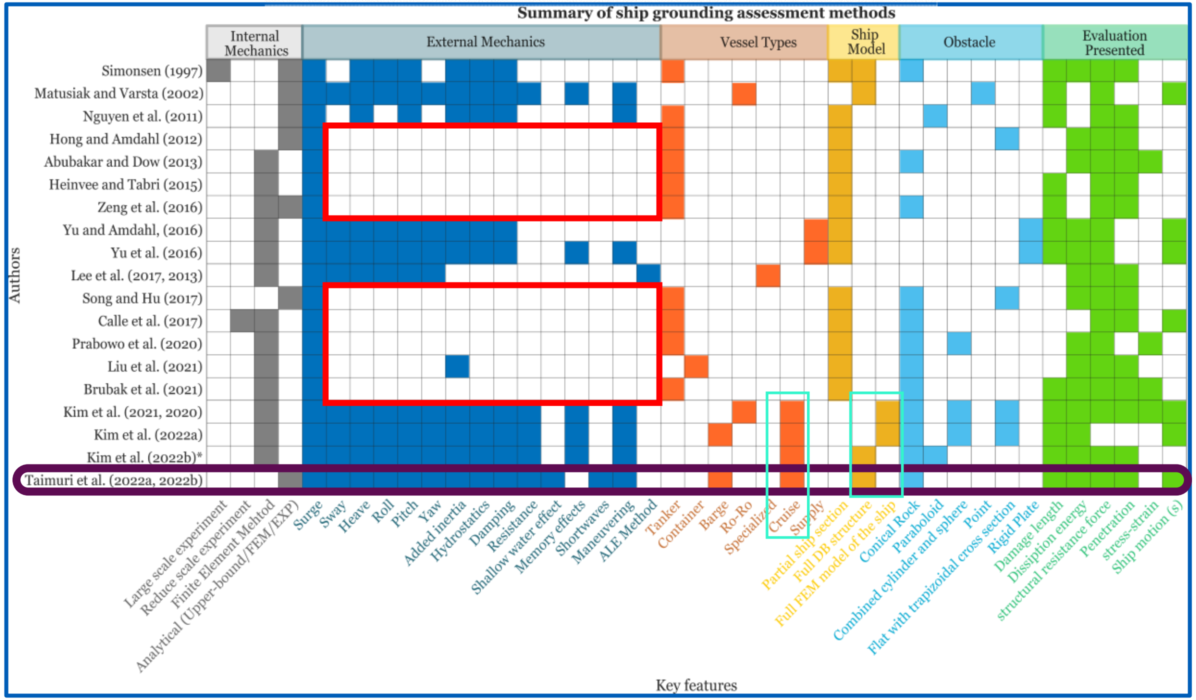
Research challenges

- High computational time
- No evasive ship dynamics
- Most models are decoupled
- Existing models are not feasible for crashworthiness, evasive and probabilistic assessment.
- The damage extents dataset of passenger vessel grounding is limited



Aims

Develop a computationally efficient and accurate ship grounding assessment method that combines ship dynamics with structural deformation under realistic operational conditions. And populates the passenger vessel damage statistics.



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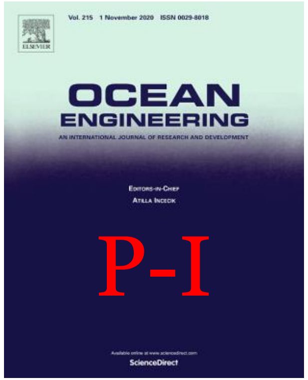
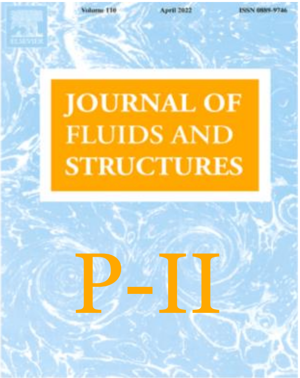
Methodology





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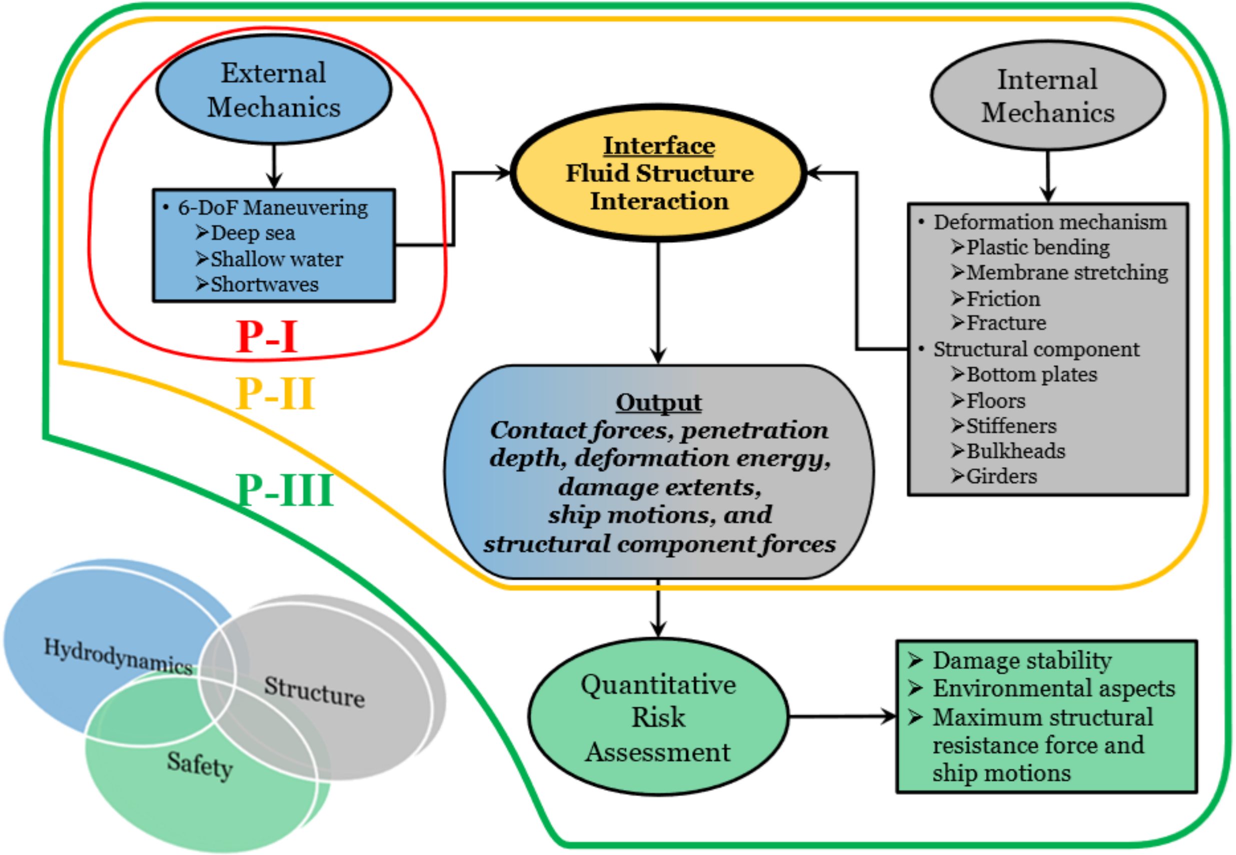
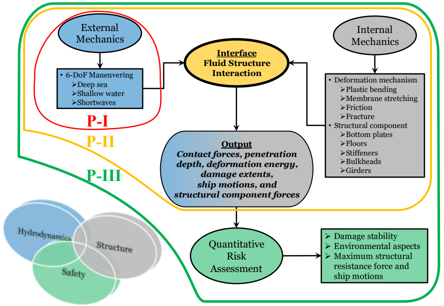
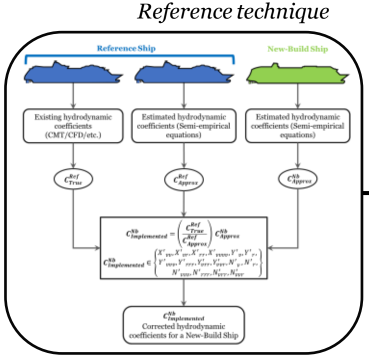
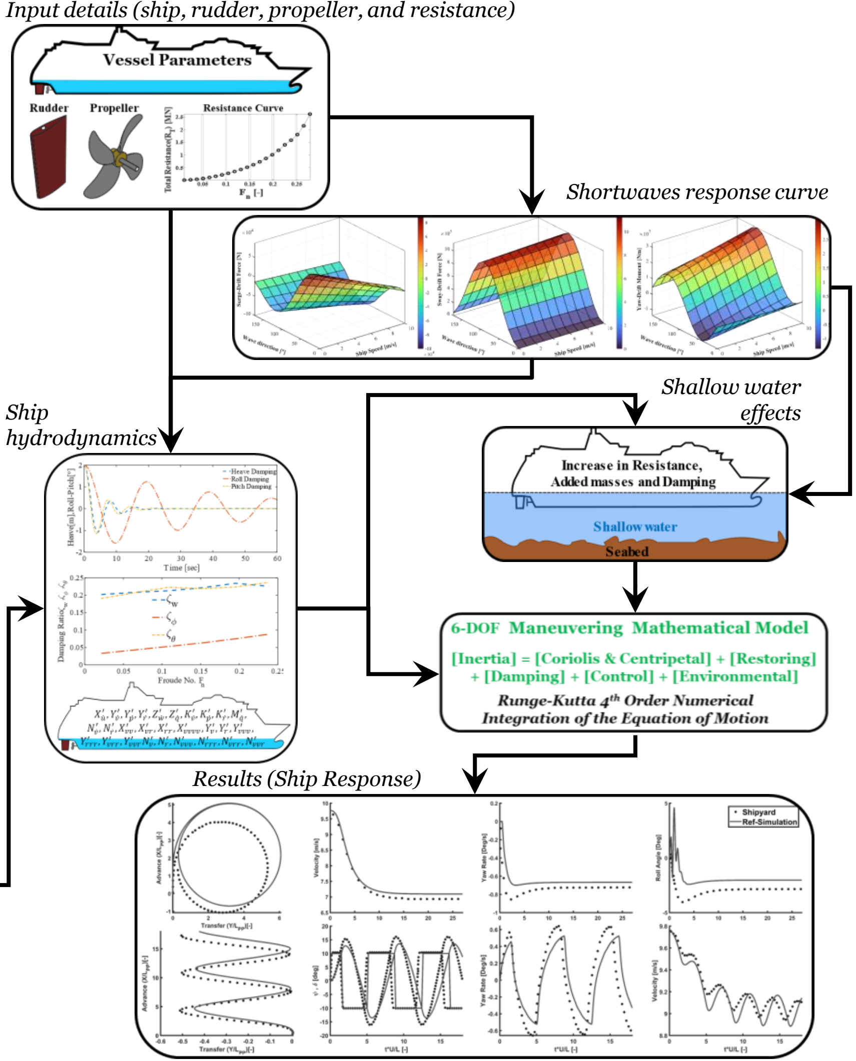


External Mechanics

- ✓ Mathematical modelling of 6-DoF Maneuvering model
- ✓ Consideration of deep sea, shallow sea, calm water, short waves, wind and ocean currents
- ✓ Single and twin-screw vessel
- ✓ A Reference technique to account hydrodynamic derivatives of twin screw vessel.
- ✓ Modelling of out of the plane motions (Heave, Roll and Pitch)

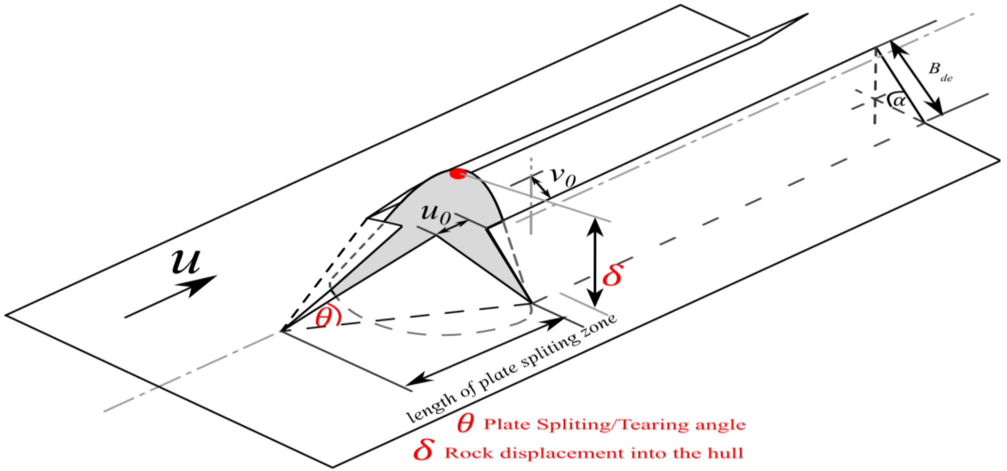


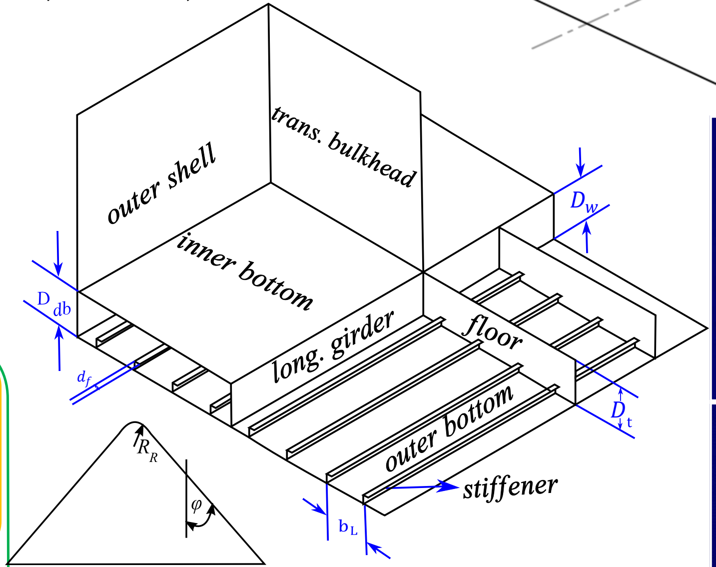


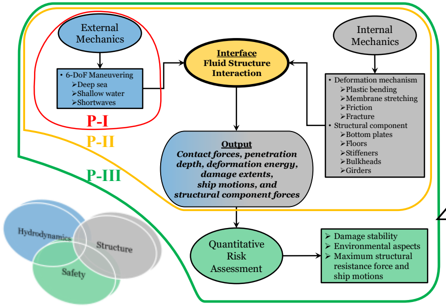


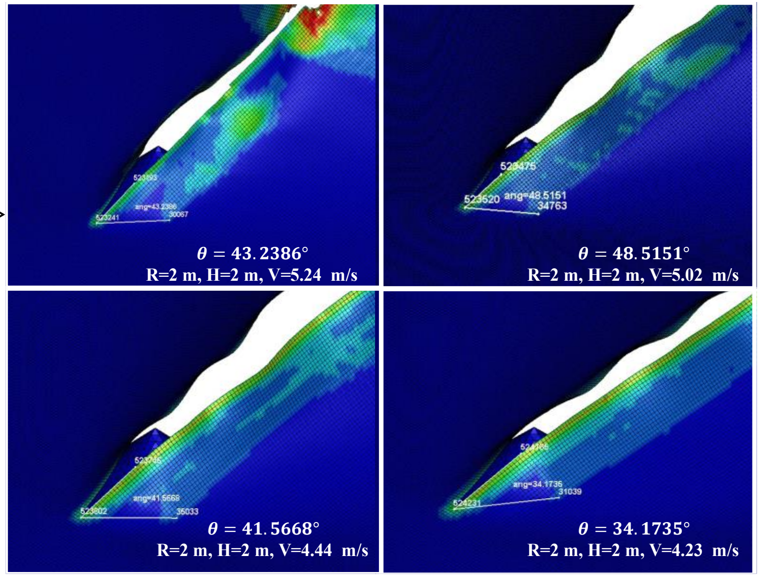
Internal Mechanics

- ✓ Motion dependent structural failure model (*Redefinition of plate tearing angle θ*)
- ✓ Consideration of general arrangement of bottom structure and major components (plate, beam ,bulkhead, etc...)



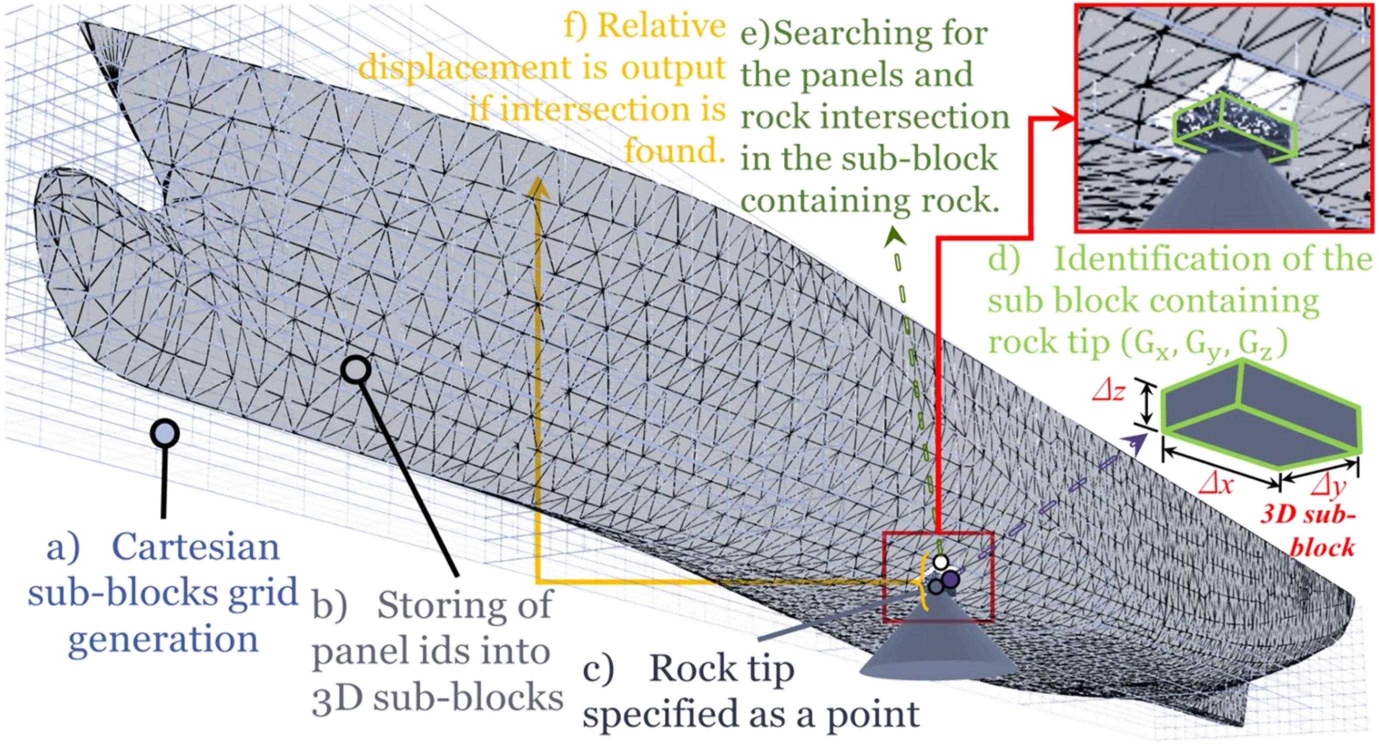


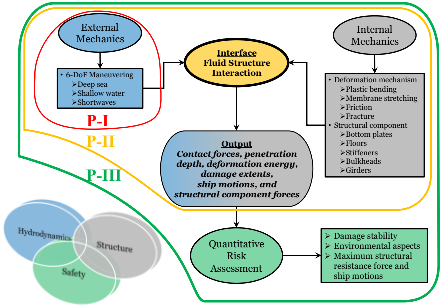




Contact coupling (Interface)

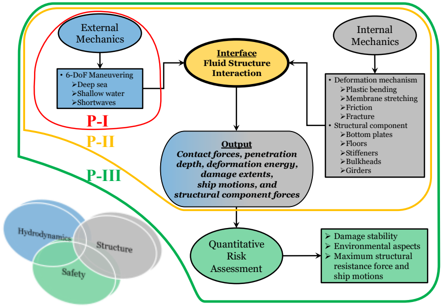
- ✓ Require hull panels, rock tip, ship location and motions.
- ✓ Hull panel stored in sub-block for *rapid search* of rock tip.
- ✓ Implementation of *ray-tracing algorithm* to identify penetration

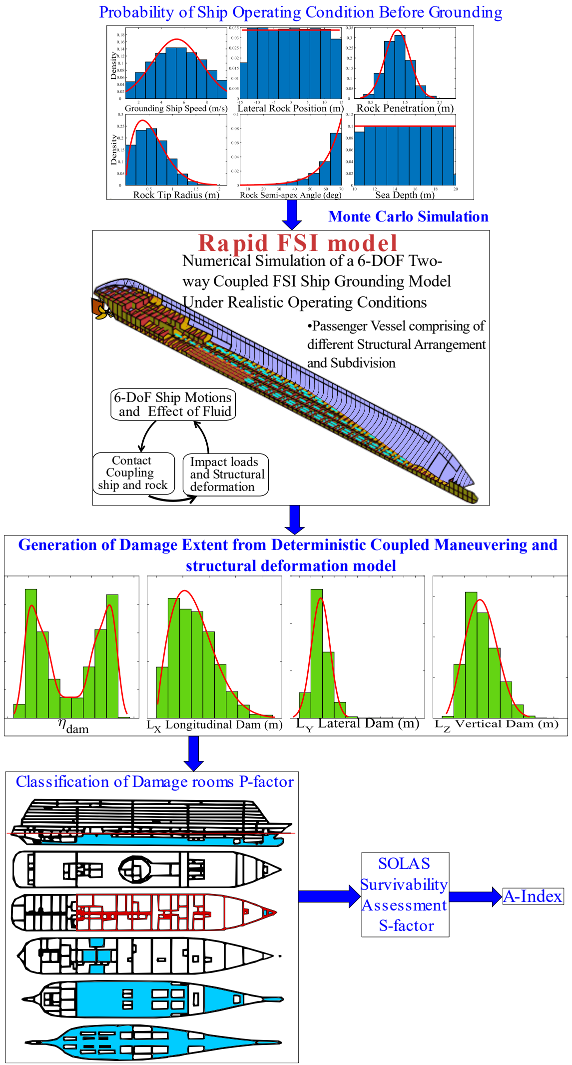




Probabilistic Damage Extent

- ✓ Use of the rapid FSI model
- ✓ Performed Monte Carlo simulations to generate the ship operating parameters and conical rock profile.
- ✓ In an event of grounding the method determines:
  - ❑ extents of actual damage,
  - ❑ the maximum resistance force of structure,
  - ❑ the maximum attained ship motions, and
  - ❑ Attained subdivision index

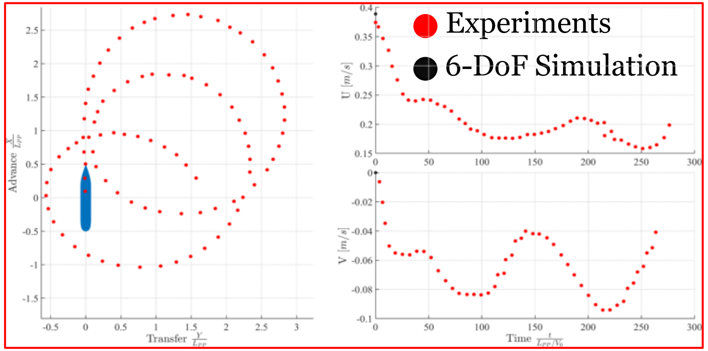


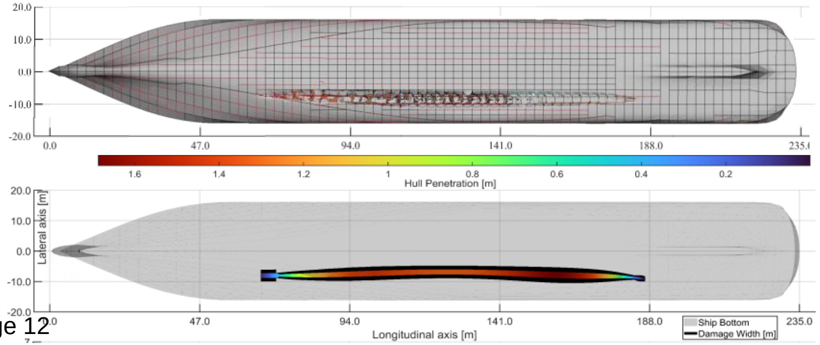


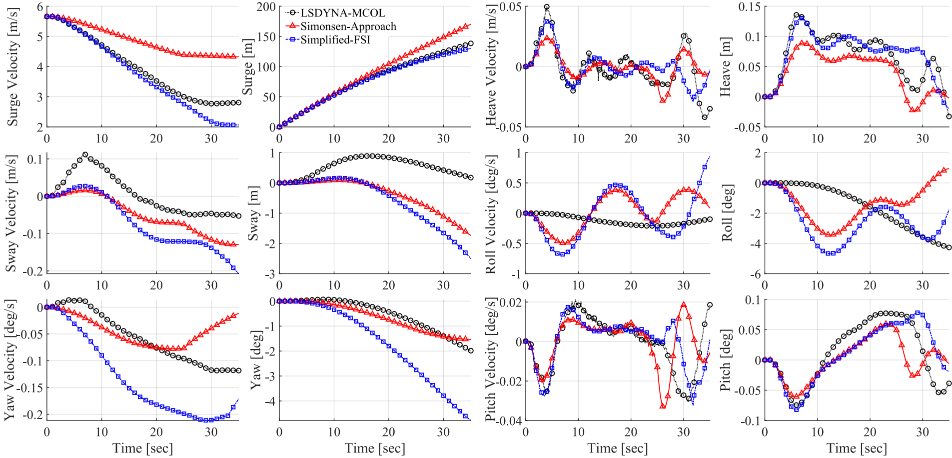
Results

- ✓ Reasonable estimates of trajectories and ship motions.
- ✓ CFD or Experiment hydrodynamic coefficient are more accurate.
- ✓ Reference technique is best choice for the initial estimation of TPTR vessel maneuvering.
- ✓ Under shortwaves conditions Sway velocities, are little overestimated.
- ✓ Ship motion dependent plate tearing angle outperforms the simplified technique of constant plate tearing angle
- ✓ LSDYNA-MCOL results matched reasonably well against rapid FSI model.
- ✓ Some LIMITATIONS observed in FSI model when simulating real ship topology:
  - ❑ Overestimation of vertical force near bulbous bow and curved regions
  - ❑ Underestimation of Lateral force when rock is fastened between two longitudinal girders.

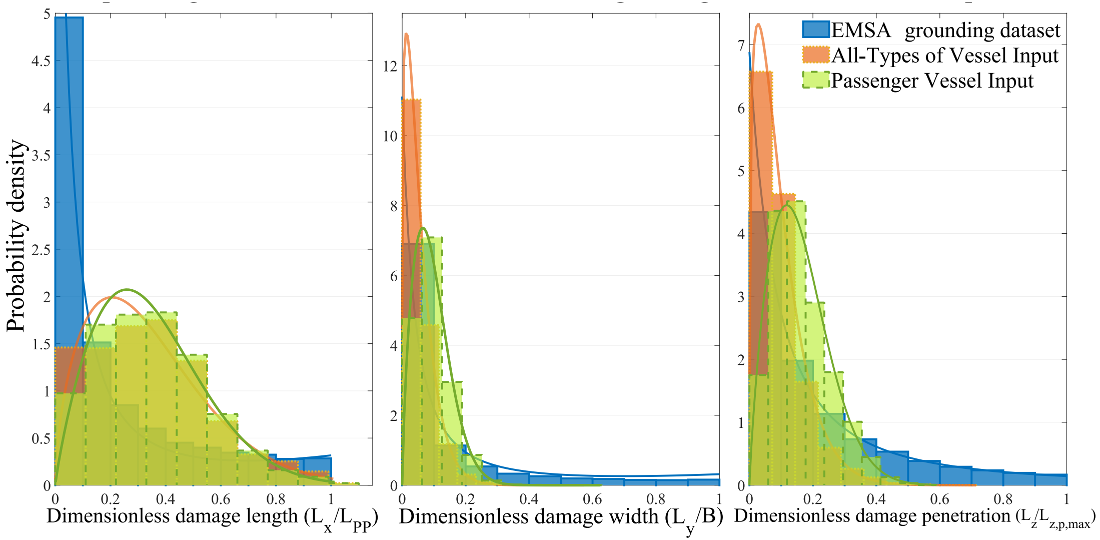
DTC Head waves maneuver



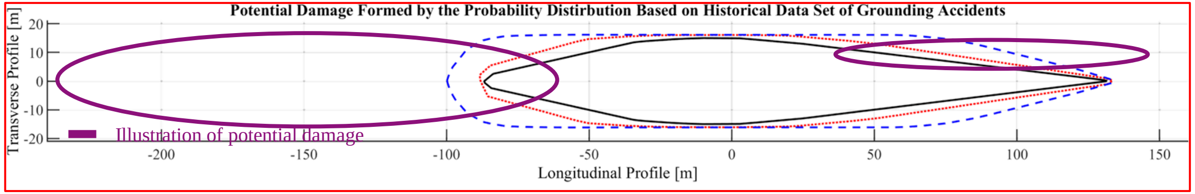




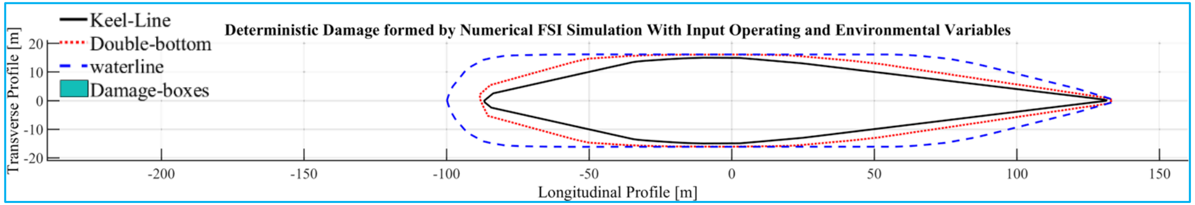
- ✓ Mean damage length output from the rapid FSI method is 55% larger than the historical database of EMSA
- ✓ Damage breadth and penetration from FSI model is 30% and 25% is lower, from FSI model.
- ✓ Little difference between deep and shallow water.
- ✓ Potential damage vs Actual damage
- ✓ Certain hull breaches outside ship domain.
- ✓ FSI model allows for a more realistic idealization of the influence of the effects of material properties and the operational conditions/environment.



Existing Distributions

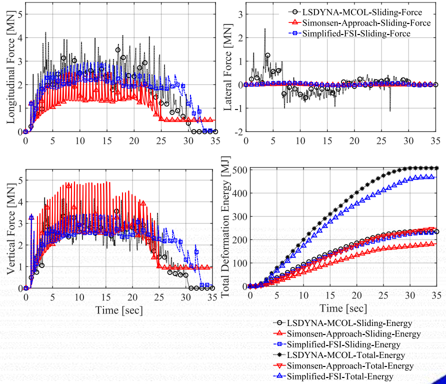


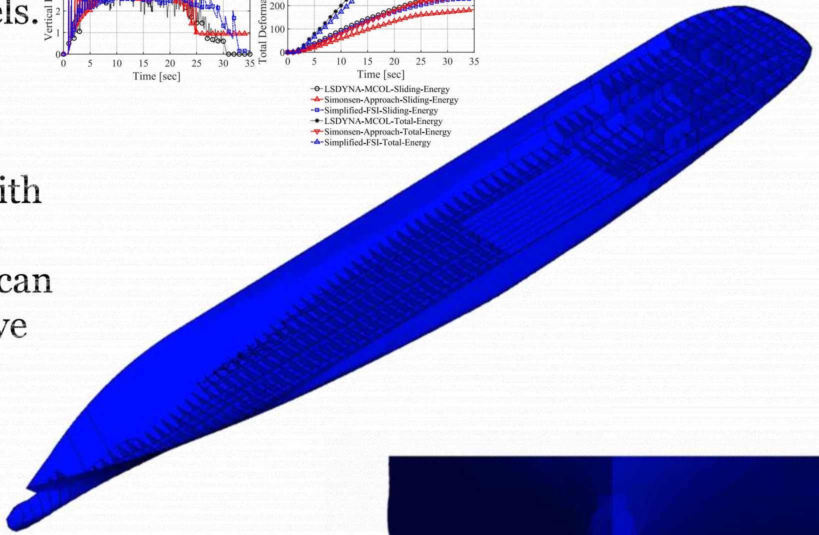
Rapid FSI-Model

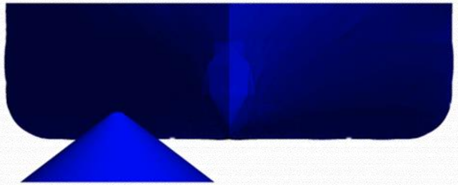


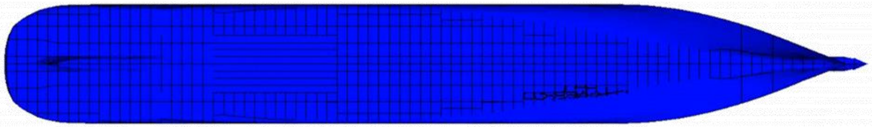
Conclusion

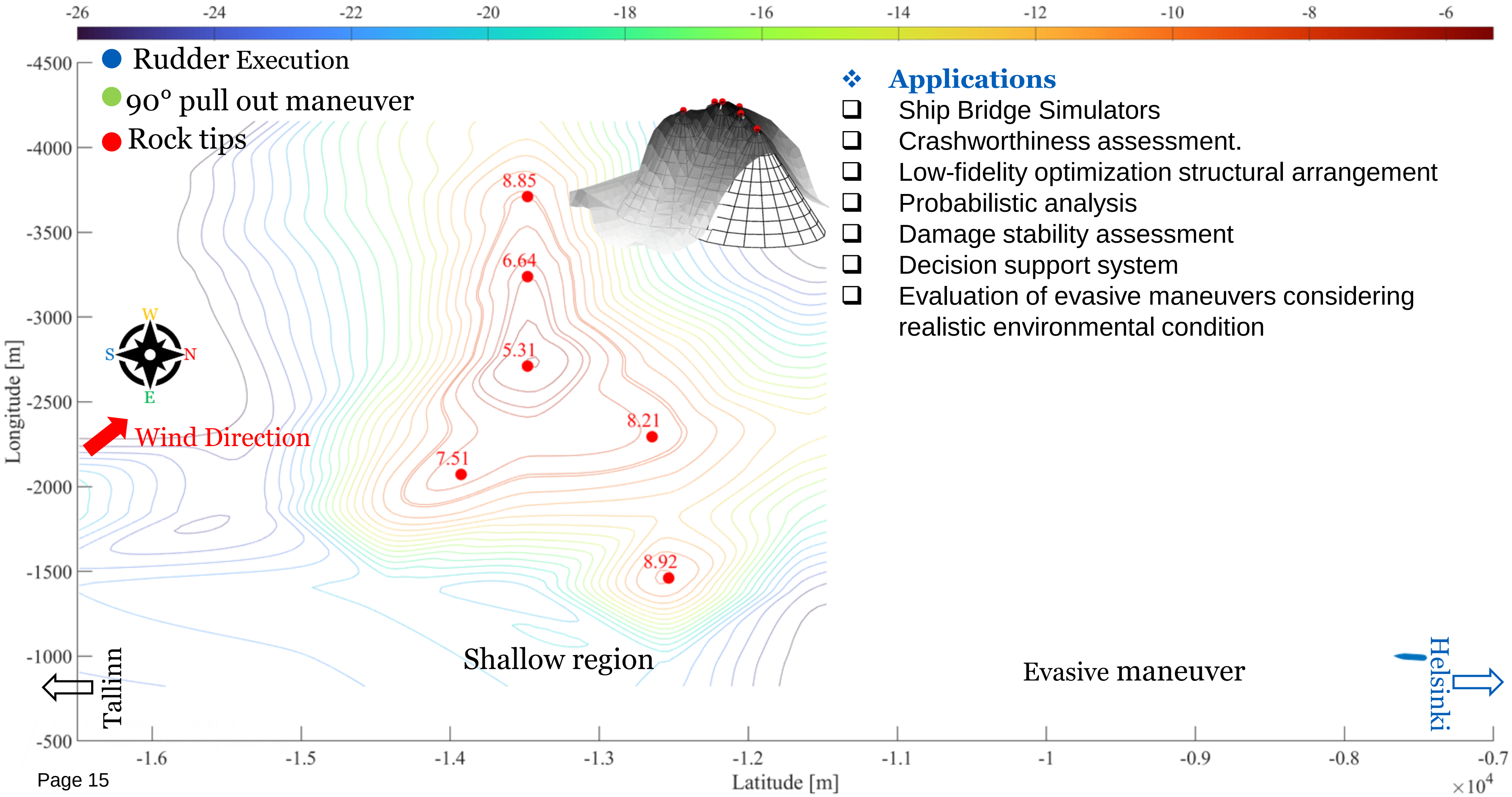
- ❖ An improved model for ship grounding dynamics is introduced.
- ❖ Reference technique is feasible for the prediction of maneuvering trajectories of existing or new-build vessels.
- ❖ Well validated maneuvering under shallow water and shortwaves conditions.
- ❖ Motion-dependent plate split angle must be used.
- ❖ Prediction of damage extent and deformation energy with simplified FSI model are generally acceptable.
- ❖ Maneuvering dynamics and meteorological conditions can be considered for structural crashworthiness and evasive actions.
- ❖ Addition of ship restoring forces, damping and 6-DoF rigid body dynamics is essential











❖ Applications

- ❑ Ship Bridge Simulators
- ❑ Crashworthiness assessment.
- ❑ Low-fidelity optimization structural arrangement
- ❑ Probabilistic analysis
- ❑ Damage stability assessment
- ❑ Decision support system
- ❑ Evaluation of evasive maneuvers considering realistic environmental condition

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Thank You !

Defense Date:
20th January 2023

Questions ?

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