Agency for Science, Technology and Research
SINGAPORE

MARITIME AI & MODELING FOR TRAFFIC SAFETY & PORT OPERATION ENHANCEMENT

Xiuju Fu
(fuxj@ihpc.a-star.edu.sg)
Senior Principal Scientist I
Maritime AI Research Programme Director

Systems Science Department
Institute of High Performance Computing

Application Areas of AI in Maritime

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AI's advantages, purposes, and requirements

Purpose: Leverage data and computing power for automatically execution of predefined, repetitive tasks.

Requirement: AI modeling, Computing, Domain/phenomenon understanding, Data quantity and quality.

Advantage: Modelling once, run in many places. Faster and more economical compared to manual, traditional processes, reducing human errors, faster, more real-time in decision-making and support

Disadvantage: Difficulty in reflecting new dynamic structure of factors, unseen situations (black swan). Performance is very sensitive to data quantity and quality.

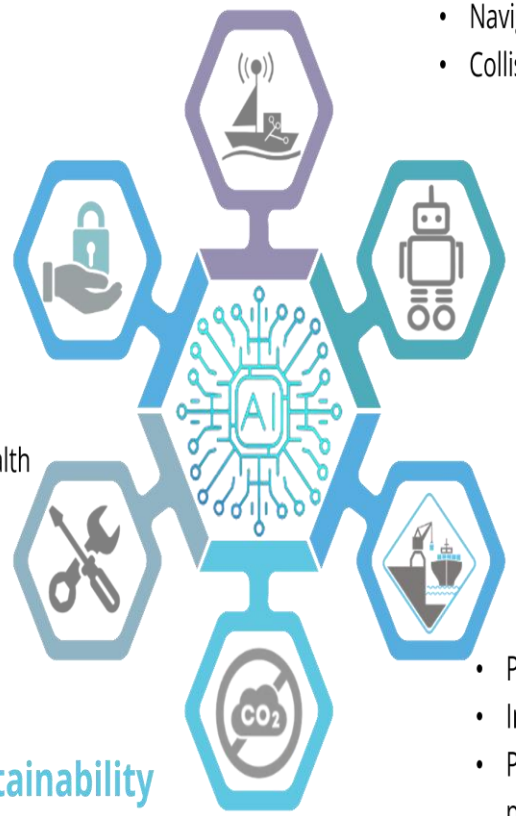
Key Research Areas of Maritime AI

Maritime Safety & Security

- Accident, incident or risk prediction
- Crew competency assessment
- Crew mental health assessment
- Fatigue screening
- Sea-state estimation
- Typhoon (hurricane) forecasting

Autonomous Shipping

- Object detection & recognition
- Navigational situation perception
- Collision avoidance for Autonomous Vessels



Maritime Robotics

- Robots for ship's hull clean and maintenance
- Underwater robots for ship inspections
- Fire robots on ships
- Anti-piracy robots

Predictive Maintenance

- Vessel engine and compressor health
- Ballast pump
- Ship propulsion system
- Hull structure monitoring
- Maritime crane

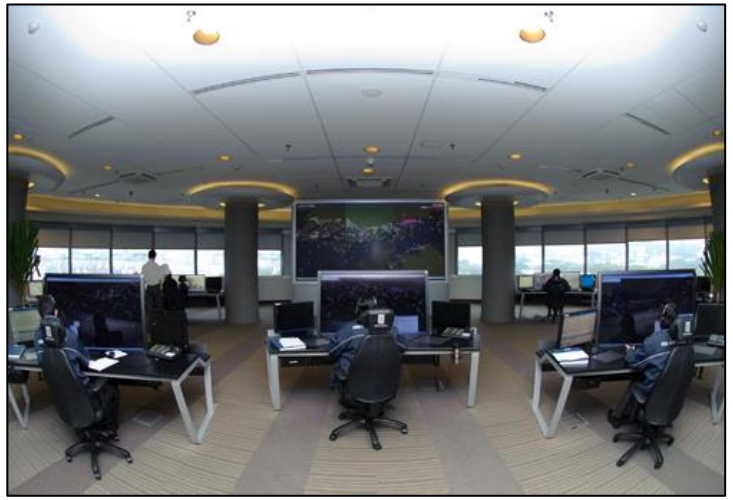
Smart Ports

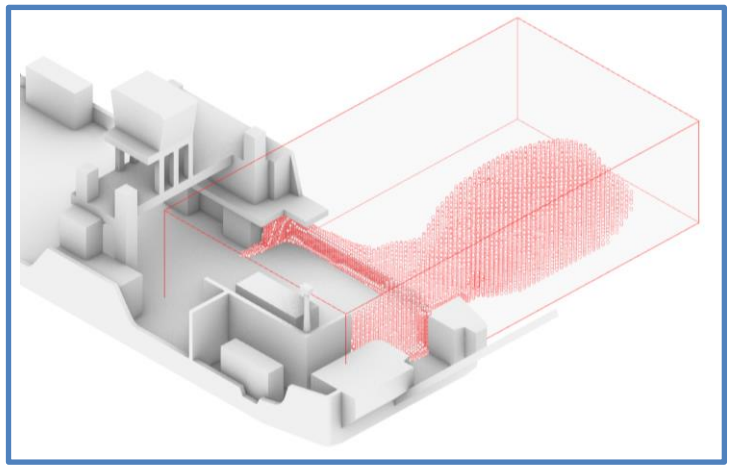
- Port situation monitoring (e.g., congestion monitoring)
- Infrastructure management (e.g., berth allocation)
- Predictive analysis (e.g., ETA and congestion prediction)
- Communication enhancement (e.g., VHF recognition)
- PSC inspection (e.g., ship candidates selection for PSC inspection)

Decarbonization & Sustainability

- Maritime emission monitoring
- Maritime emission estimation/prediction
- Maritime emission reduction/optimization

AI for Decision Supports to Enhance Maritime Safety





Safety is paramount for maritime sector.

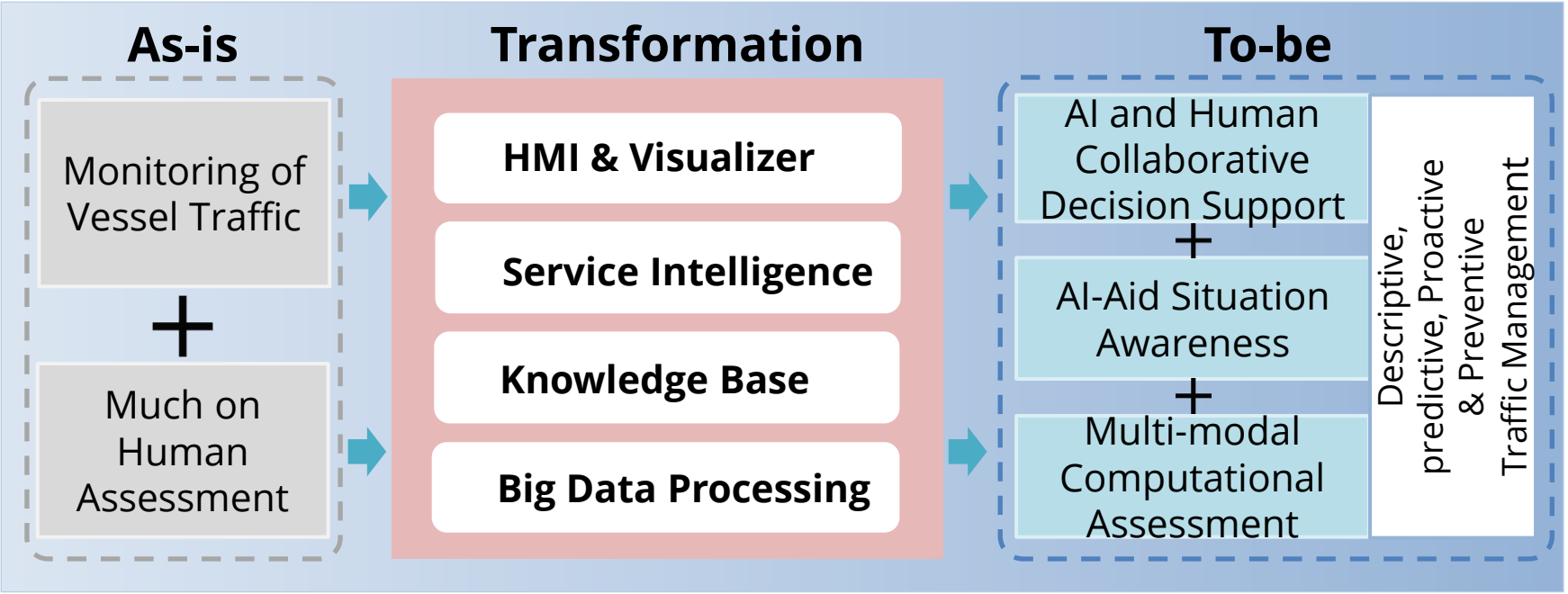
The existing VTS(Vessel Traffic System):

1) **Engrossed by "passive mode"** which requires tedious human labor and especially **rely on Vessel Traffic Services Officer (VTSO)' professional experience and skills**
2) **Without a knowledge base** to support advanced services of intelligence
3) **Lack features like intelligent solutions** on collision risk detection(such as using linear model), and a set of **proactive add-on features like hotspot forecasting** etc.

Bunkering of new fuels:

1) **Careful assessment** is needed for preventing accidental leakages for bunkering and handling of marine alternative fuels

VTS Transformation from “passive” to “proactive”



AI models are not taking over the role of human operations, instead AI models play a role that provides strong assistance to perform some essential tasks.

- Manage multi-modal data (such as AIS data, radar data, video surveillance and communication voice etc.) for **effective computational assessment**.
- **Advanced AI models** running in the backend for improved accuracy, which **extends the prediction window in both temporal and spatial dimensions** for better and time-forward situation awareness.
- **To automate the processes and work in proactive manner**, allowing earlier discovery of potential risks in advance and hence action-taking to mitigate risks and avoid last-minute actions.

Our paper - **Next Generation Vessel Traffic Services System – from “Passive” to “Proactive”** published by **IEEE Intelligent Transportation Systems Magazine**

Maritime AI and big data research to empower the next Gen VTS

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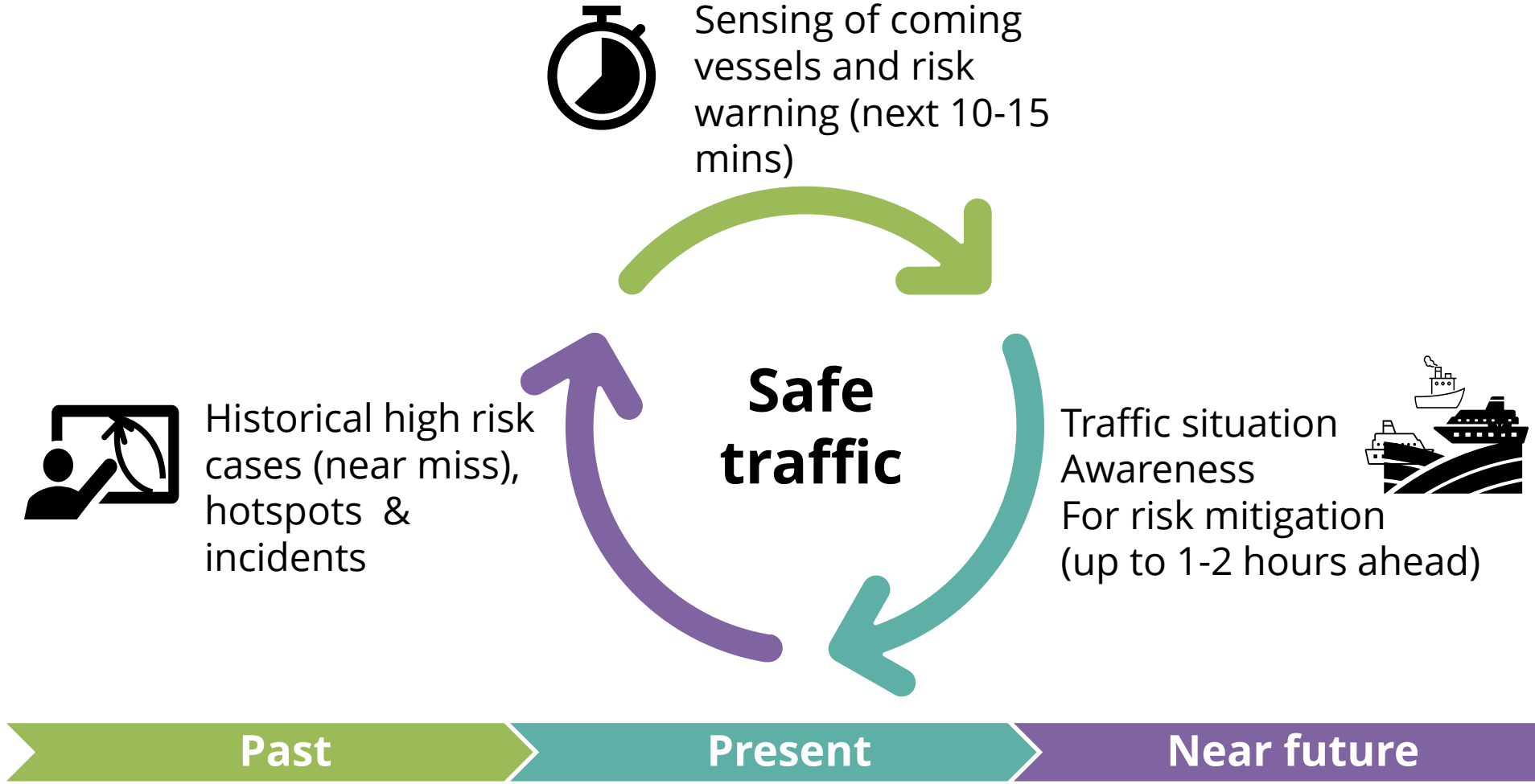

Vessel's turning status prediction for advanced risk warning

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Objective

Develop predictive model to predict/detect **vessels' turning (changing navigation status);** Intelligently monitor vessels' **crossing-channel intentions**

Research Foci

Big volumes of traffic data processing

Large-scale human-annotated data

AI based vessel turning status prediction to provide inputs for enhanced vessel's trajectory prediction and risk warning

Deliverables

Accurate turning status prediction **(92.3%)**

Integrated with trajectory prediction model for **better vessel turning trajectory prediction**

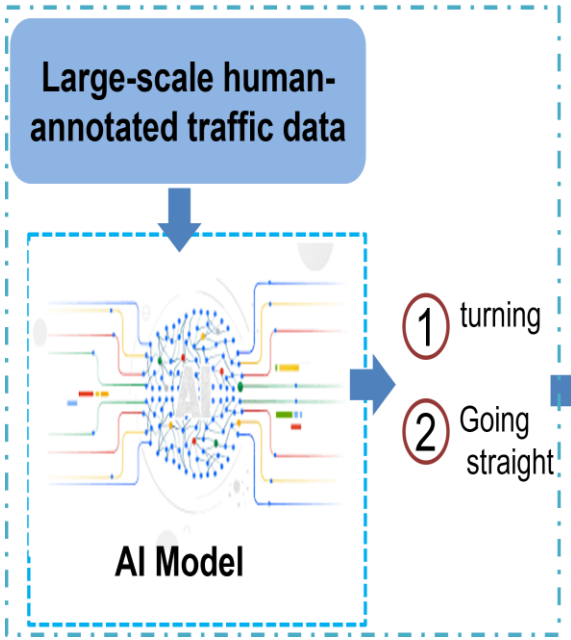
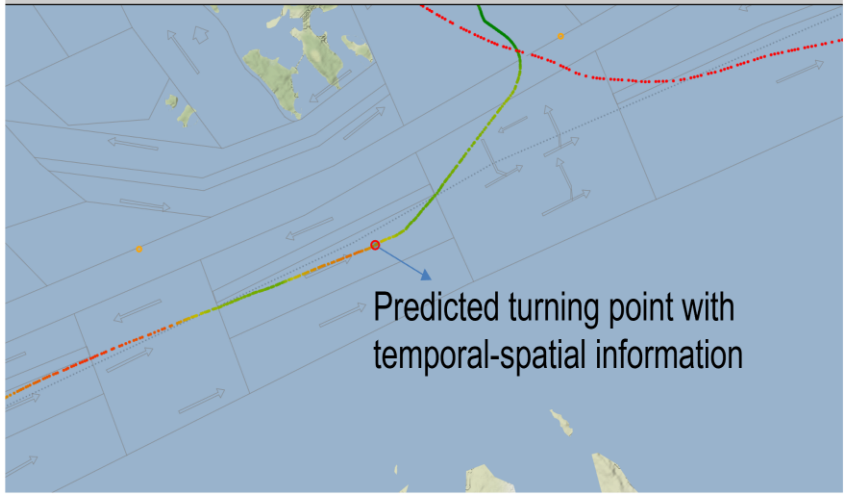


Table 1: prediction performance

Accuracy	Precision	Recall	F1-score	AUC
92.30%	88.27%	97.67%	92.73%	92.27%



IHPC's turning prediction model

Our paper is submitted to IEEE Trans on Intelligent Transportation Systems

Collision risk warning model for earlier warning (10-15 mins ahead)

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Objective

Establish intelligent collision alert function that advances the existing linear model – **achieving earlier warning and better accuracy**

Research Foci

Leverage on big data intelligence to design and develop **non-linear vessel movement** prediction
Many rounds of workshops with **MPA's Port Operations Control Centre (POCC)** operators for model validation.
Testbedding with real-time traffic at **MPA Living Lab**

Deliverables

Model using nonlinear movement prediction-based collision risk alert

Dashboard that visualizes the collision risk services

Traffic hotspot prediction for potential traffic hotspots (30mins ahead)

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Objective

Establish **traffic dense hotspot forecasting function** serving as an add-on features for **proactive maritime traffic safety management**

Research Foci

Situation awareness of traffic dense hotspot by aggregating vessels' long term (up to 30 min) trajectory prediction through big data intelligence

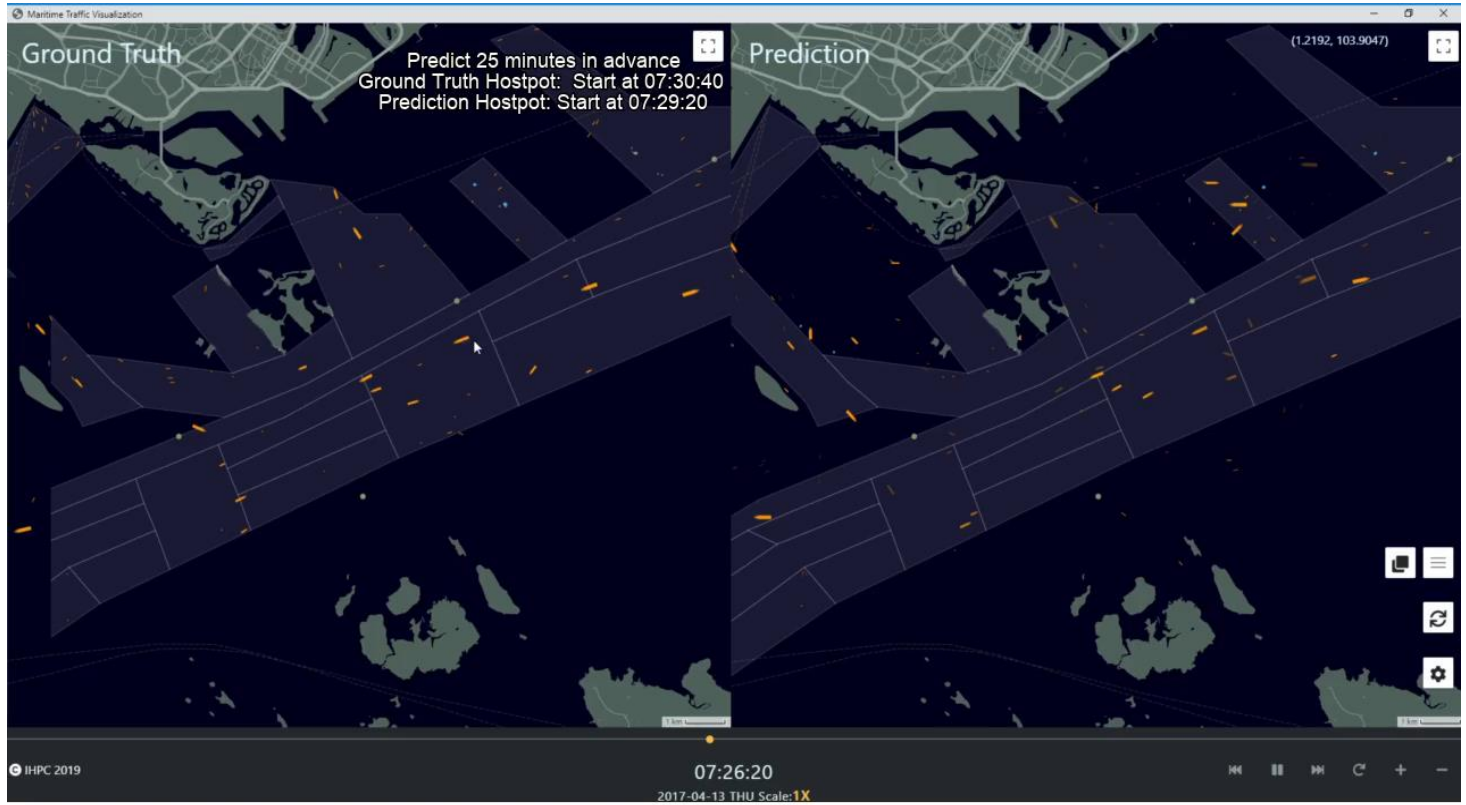
Many rounds of workshops with **MPA's Port Operations Control Centre (POCC)** operators for model validation

Testbedding with real-time traffic at **MLL**

Deliverables

Model using nonlinear trajectory prediction-based traffic dense hotspot situation awareness up to 30 min in advance

Dashboard that visualizes the traffic dense hotspot forecasting features over live traffic



IHPC's hotspot forecasting for early situation awareness

CFD-based risk assessment for accidental leakages of new fuel bunkering

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Contact: **nguyenvt@ihpc.a-star.edu.sg**

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Objective

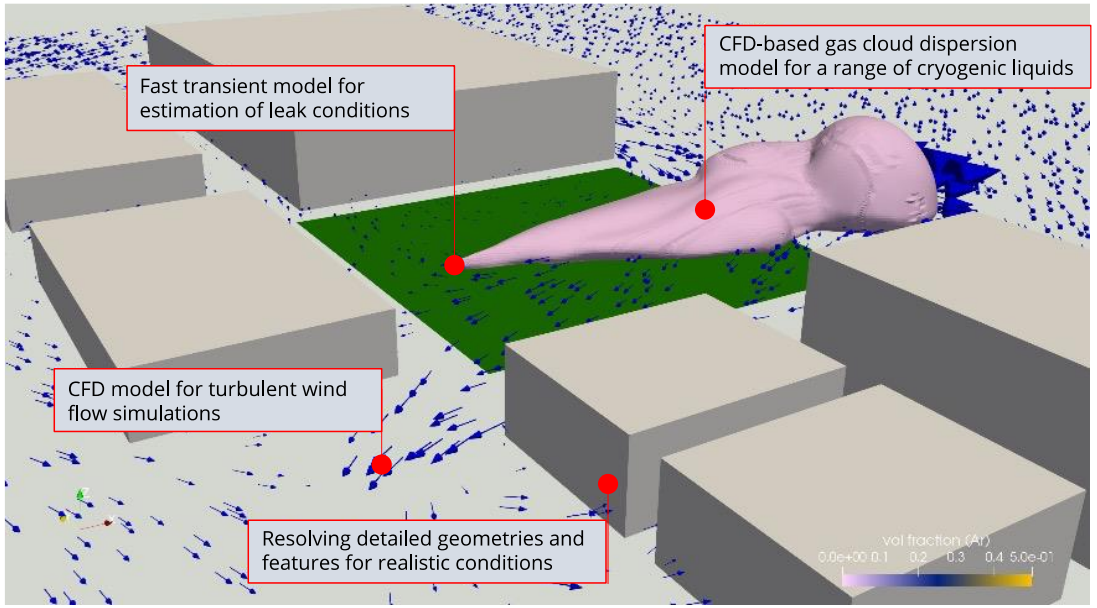
Developing a **high-fidelity CFD-based quantitative risk assessment** of accidental leakages for bunkering and handling of marine alternative

Developed Capabilities

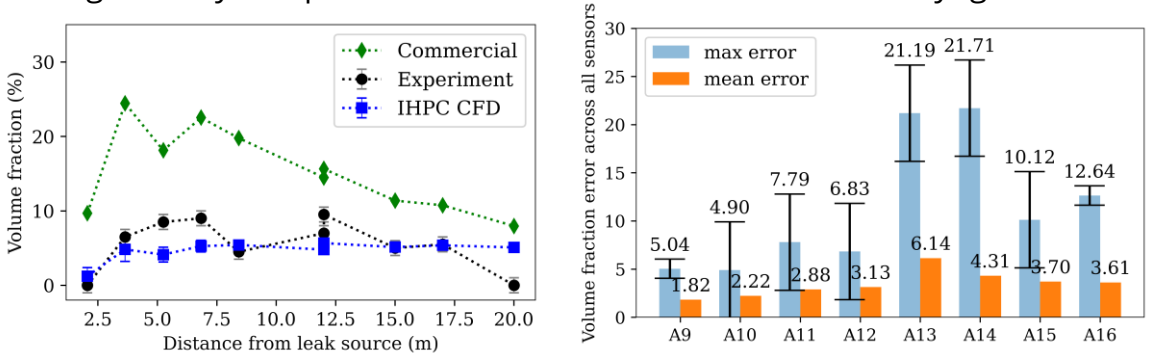
- **Transient leak model** coupled with experimentally **validated CFD approach** for simulations of gas cloud formation and ignition probability for accidental leakages.
- Rain-out and multiphase release of cryogenic liquid
- Surrogate modelling for fast prediction of gas plume dispersion
- Uncertainty quantification of environmental conditions (e.g.: wind speed and directions) on gas plume dispersion
- Evaluation effectiveness of mitigation measures

Key Outcomes

- Validated CFD approach with field data showing **superior performance** comparing with existing industrial tools.
- Application of the developed framework for design of LNG, hydrogen fuel-cell; and ammonia powered vessels
- Risk assessment for **bunkering of potential alternative fuels (methanol, ammonia)**



High fidelity computational framework for simulations of cryogenic leaks



Comparison of maximum concentration at sensor locations between field data and numerical tools for one of the experimental runs. CFD is the present framework.

Maritime AI research for enhancing port operation

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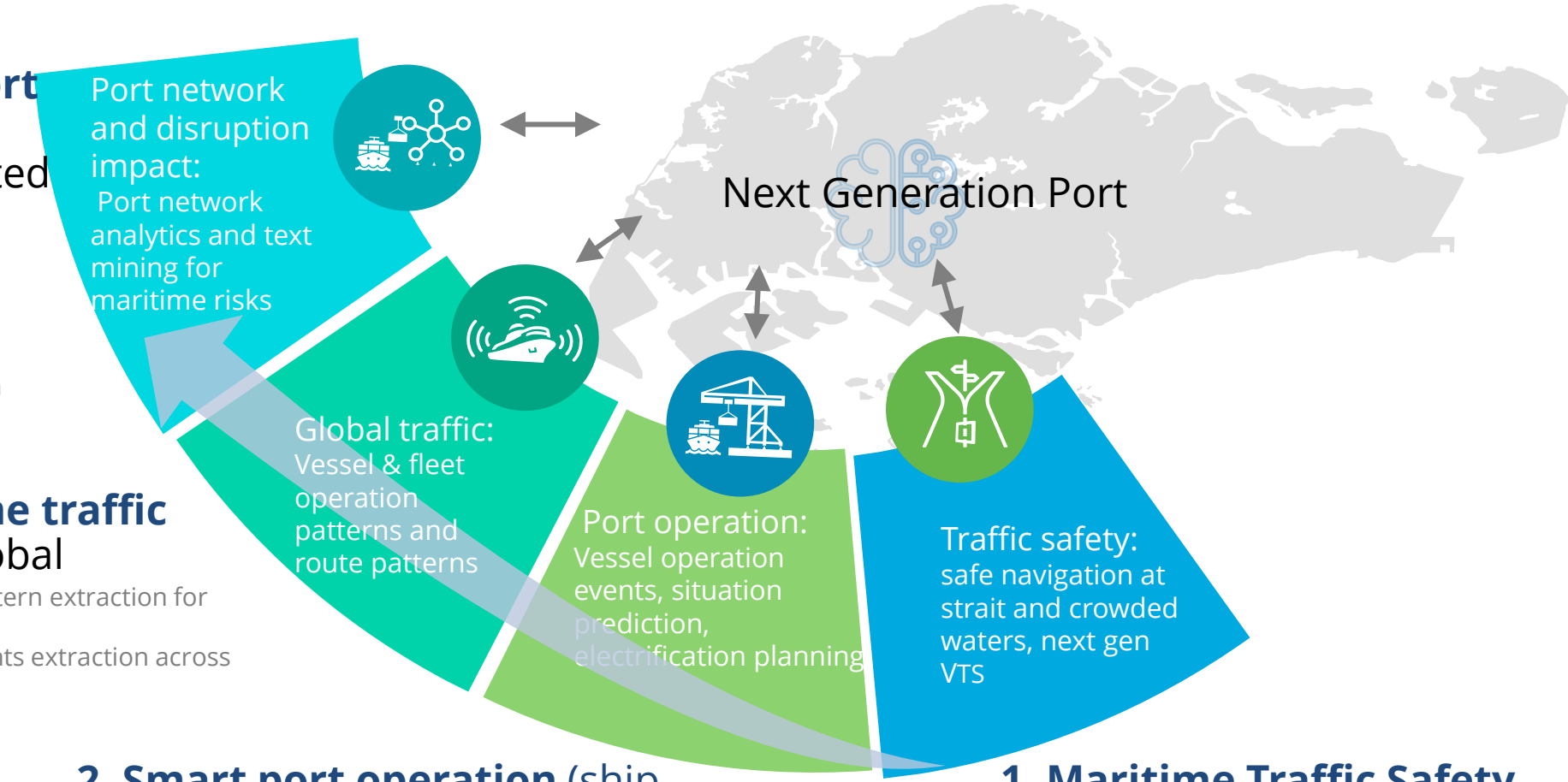
4. Global Maritime Port Network
From Siloed to connected

- Maritime network construction and key node detection
- Complex network analytics
- Maritime supply chain network risk analytics
- Text mining for maritime disruption events



3. Global Maritime traffic
from local to global

- Global maritime traffic pattern extraction for routing analytics
- Vessel/fleet operation events extraction across ports
- ETA prediction etc.

2. Smart port operation (ship, fleet, terminal, port)
From single to multi-systems

- Port traffic based emission study
- G&B, tanker and container vessel operation planning, optimization and operation event detection
- Fuel consumption optimization within port

1. Maritime Traffic Safety Research
From passive to proactive

- Dynamic spatial-temporal risk analytics based on data
- Near miss case detection
- AI-based collision risk warning
  Traffic hotspot and situation awareness

Many AI-based predictive models for our port-traffic enhancement

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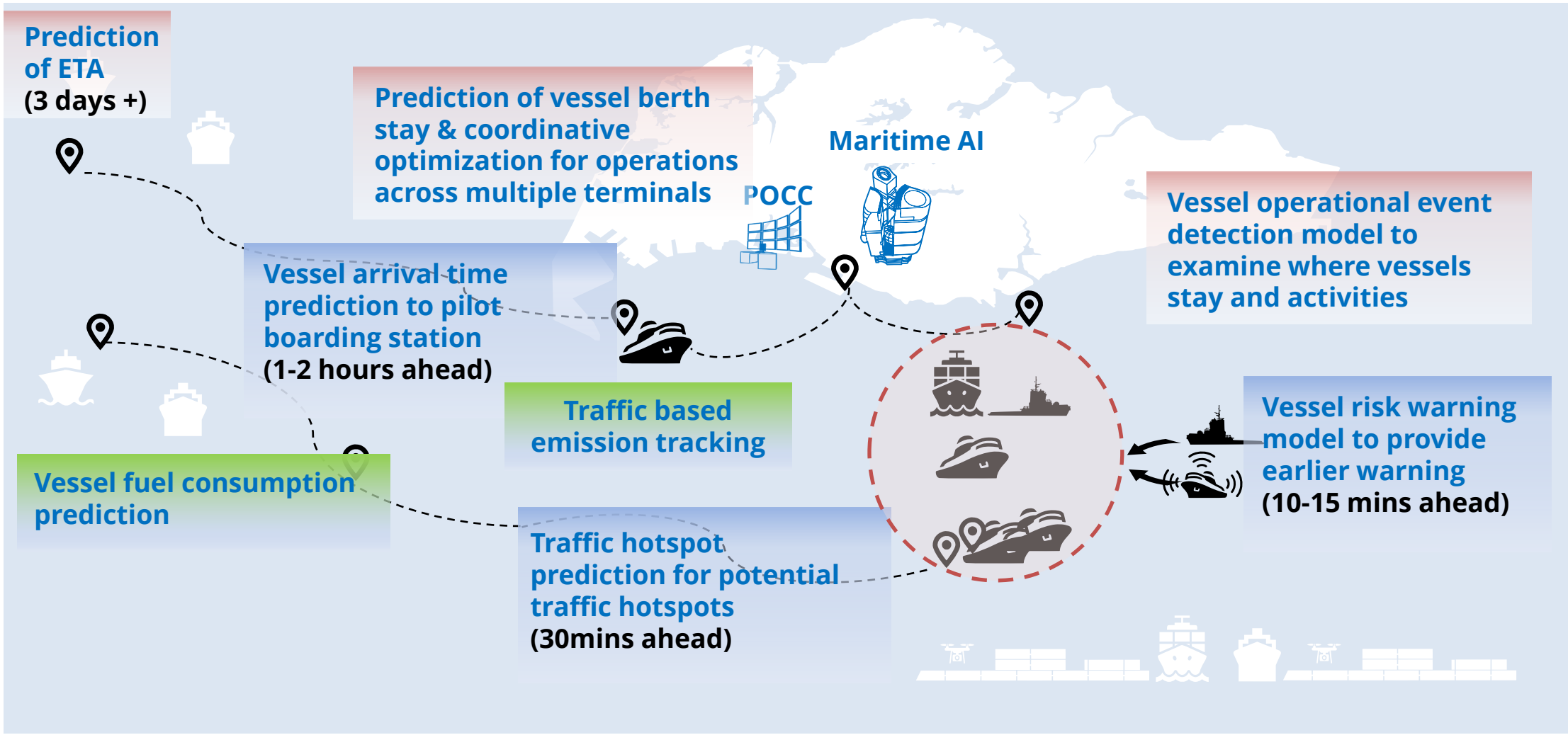
Traffic Management Port Efficient Operations Vessel fuel/energy consumption prediction

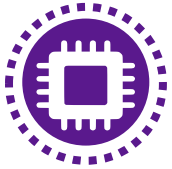


Maritime AI Development: Needs & Barriers

1. Maritime data are far from full utilisation due to data issues; R&D is needed to exploit maritime data to create values
2. While there are companies adopting AI, many are still new or at nascent stage
3. Marrying maritime domain knowledge and AI modeling is critical for building up maritime AI ecosystem
4. Need for maritime AI tools and automation platform to accelerate adoption
5. AI capabilities are needed along various parts of value chain, and prioritisation of high impact use cases is needed to demonstrate value for scaling up

Maritime data silos, lack of data quality and quantity

Lack of easy-to-use AI models & automation tools



Obstacles in computational efficiency when scaling up

Lack of solid AI service examples with trust & explainability

Takeaways from the 1st **Maritime AI Workshop** and discussions with more than **40 maritime companies**

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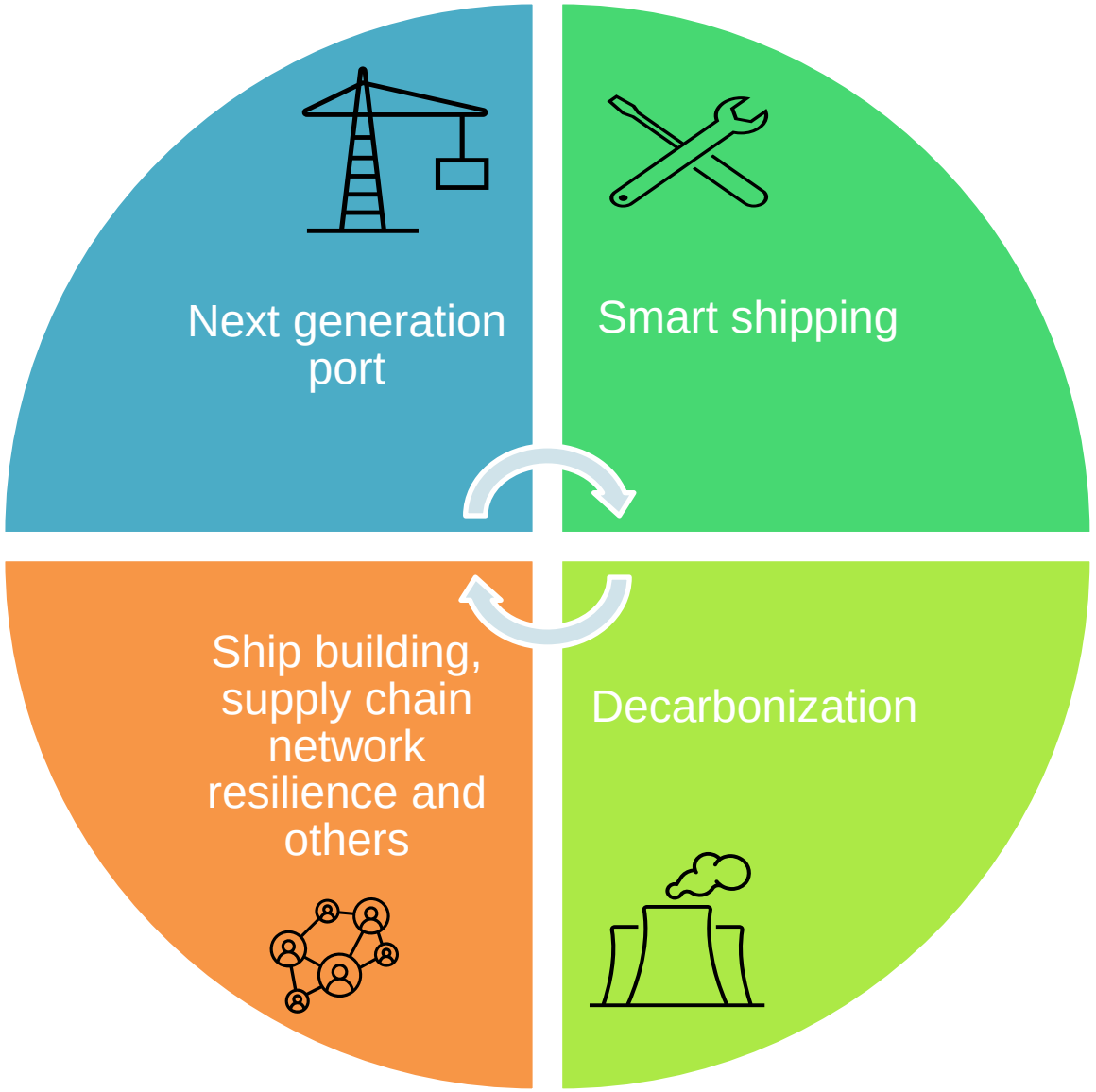
Use Case Examples under the MARS Programme
for Maritime AI Capabilities Development



Joint development with industry partners

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Summary

- There is great potential for maritime AI to assist maritime traffic and port operation enhancement towards incident-free traffic

- IHPC/A*STAR leads the Maritime AI Research Programme (MARS)
  - In collaboration with partners to develop maritime AI capabilities, aiming to advance efficiency, safety and decarbonization within the maritime ecosystem

- Maritime AI research and development requires a community-based approach and we welcome more collaboration.

IHPC's maritime AI research: https://www.youtube.com/watch?v=PIh_BsHb63g&t=7s

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THANK YOU

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Contact: fuxj@ihpc.a-star.edu.sg