The Current Technological Progress and Future Work Priorities of MASS

2023.11

MASS CODE ROADMAP

2017

MSC98
- Scoping exercise on autonomous vessels put on agenda

2018

MSC99
- Framework for a regulatory scoping exercise

MSC100
- Regulatory scoping exercise on Maritime Autonomous Surface Ships

MSC101
- Interim guidelines for MASS trials approved

2019

MSC105
- Approved a road map containing a work plan for the development of IMO instruments for MASS

2021

MSC103
- Regulatory scoping exercise on Maritime Autonomous Surface Ships

2022

MSC104
- Goal-based instrument to be developed

MSC106
- Made further progress on the development of a goal-based instrument regulating the operation of MASS

2023

MSC107
- Preliminary formation of a common position on the first and second parts of the rules
- Propose guidance for the third part of the review

MSC109
- Approve non-mandatory MASS CODE

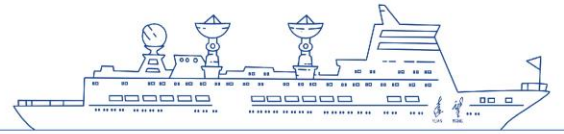
2024

2026

MSC111
- Approve mandatory MASS CODE
- Enter in to force on January 1, 2028

non-mandatory in 2024->mandatory in 2028

MASS CODE--MSC 107



MASS Code Draft 01

- **Preliminary formation of a common position** on the PART I & PART II of the rules
- Propose guidance for the third part of the review

Relationship with SOLAS 02

- SOLAS Convention **cannot be fully applied** to MASS
- **Additional requirements need to be developed** to accommodate risks arising from autonomous navigation or remote control

Relationship with COLREGs 03

- COLREGs **are fully applicable to MASS**

Relationship with STCW 04

- STCW **applies MASS for seafarers**
- STCW **is not suitable for remote operators**

Update road map 05

- Non-mandatory rules completed and approved by MSC 109 in 2024
- Mandatory rules approved by MSC 111 in 2026

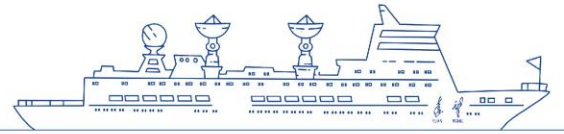
MASS-ISWG 2

Application

The provisions contained in this Code should be applied to **MASS Cargo Ships** ~~of 24 m in length 500 gross tonnage and over~~ **in international trade** ~~which are~~ **not high-speed crafts**~~,~~ as well as any associated Remote Operations Centres (ROCs).

The Code applies to **cargo ships to which SOLAS chapter I applies which have functions that enable autonomous or remote operations including any associated ROC(s)** [when the Administration deems it that direct compliance with other/existing instruments is not practicable].

MASS-ISWG 2

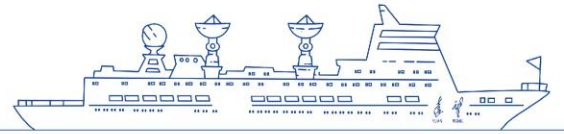


Approval process

	Preliminary design development	Preliminary design approval	Final design definition	Testing	Final approval	Operation**
Preliminary design documents	X*	X				
Drawings and information documents		X	X		X	X**
Risk analysis		X	X		X	X**
Task allocation summary		X	X		X	X**
Approval basis	X*	X	X	X	X	X**
Regulatory gap analysis		X	X			
Verification and validation definition		X	X			
Testing and verification reports				X		

* - High level only
** - In case of changes in the approved assumptions and conditions]

MASS-ISWG 2



Surveys and certification

MASS certified by the MASS Code need to have all the relevant SOLAS certification (under chapter I and others, where applicable)

In addition to conventional certificates, MASS would need a MASS certificate which lists all the equivalences/exemptions to relevant mandatory instruments, most notably SOLAS, following the principles of MSC.1/Circ.1455

MASS and ROC certificate should outline the specific functions for remote/autonomous ops (modes of operation the MASS), as well as limitations of operations

The ISM approach should be used for ROC certification, as well as technical certification for MASS and ROC (separate certificates)

Risk assessment is the basis for MASS certification

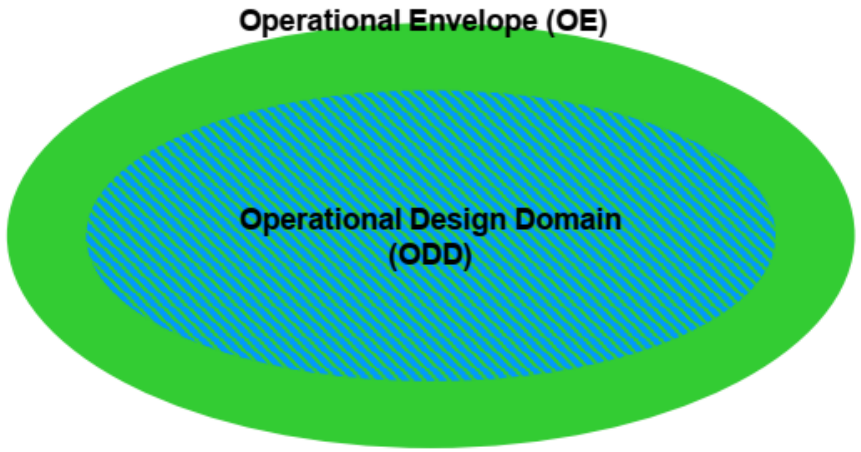
Interim certificate for MASS trials prior to issuing MASS certificate (for management aspects only, not technical aspects)

MASS-ISWG 2

Description of OE and ODD

- *Operational Envelope (OE)* describes the operational capabilities and limitations of MASS, including personnel involvement.
- *Operational Design Domain (ODD)* of ANS means the navigation condition in which ANS can work properly, in order for MASS to achieve its Concept of Operations (ConOps), and describes the operational range of the autonomous system, not including personnel involvement.
- As shown in the figure below left, the range of the ODD is generally smaller than that of the OE, and it depends on the system specification as MASS performs its functions by a combination of ANS and personnel.
- In case of conventional ship, there are no ODD and only OE, i.e. they are all green areas;

  on the other hand, in case of an unmanned and fully autonomous ship with no human involvement at all, ODD and OE are perfectly equal, i.e. they are all blue areas.
- The table below right shows an example of ODD elements, which includes sea conditions and environmental conditions.



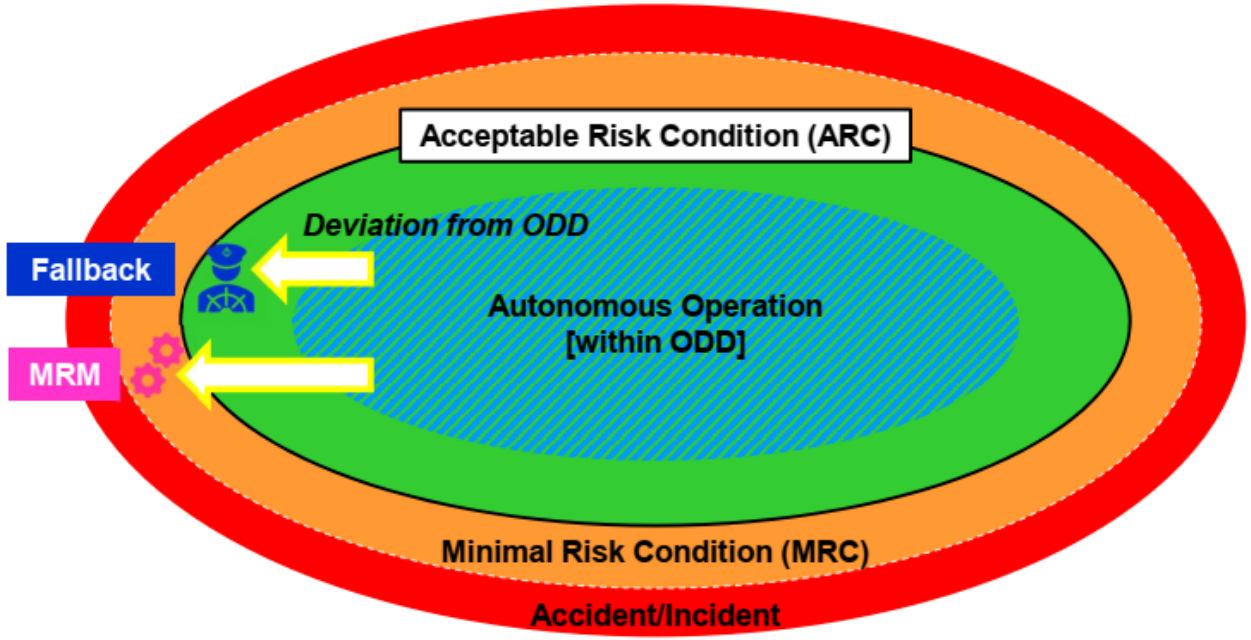
Example of ODD elements

Sea conditions	
Navigational area	Designated routes
Degree of congestion	Low congestion (No more than 8 vessels in 3 NM range)
Environmental conditions	
Meteorological and oceanic phenomena	Wind speed less than 10m/s Wave height less than 1m Sight range more than 1000m
Time	Day/night
Internal state	
State of the system	No errors
Equipment required for navigation	No errors
Others	No fire or other emergencies

MASS-ISWG 2

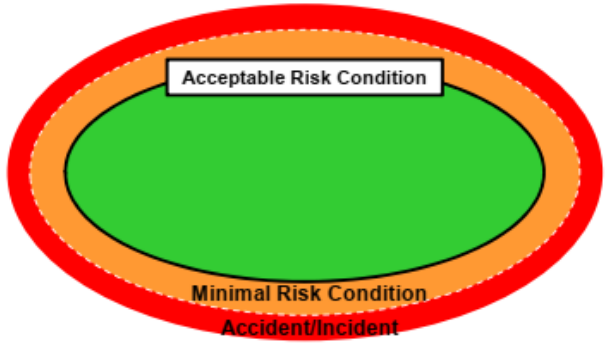
Fallback and Minimal Risk Manoeuvre (MRM)

- *Fallback* means allowing the system to continue operating under incomplete or limited conditions and the mechanism (degeneracy), including requiring personnel intervention.
- As shown in the figure below, when MASS is operated in blue area, it can continue the autonomous operation, but if it deviates from ODD, it should remain in green area, i.e. Acceptable Risk Condition, by fallback response and can continue the normal operation with personnel involvement.
- In case where MASS cannot stay in green area due to changes in the situation, MRM (Minimal Risk Manoeuvre) should be performed to stay in orange area, i.e. Minimal Risk Condition. In such a case, normal operation can no longer be continued, but it will maintain a least safe state to avoid the worst-case scenario (Accident/Incident).



- CONVENTIONAL SHIP -

- As conventional ship is operated by personnel on board, it does not have area of Autonomous Operation (blue area).
- Conventional ship is basically operated within Acceptable Risk Condition (green area), so transition from blue area to green area, i.e. fallback, is specific to MASS.



EU-AUTOSHIP

Targeting coastal short-sea shipping and inland waterways, aims at speeding-up the transition towards a next generation of autonomous ships in EU

Demonstrators

- 350t inland waterways barge
- 1462t short sea feed carrier

Key Technologies

- New Intelligent Awareness System and an Artificial Captain
- New Intelligent Asset Management and advanced simulation and data analytics
- New Digital twin and Artificial Chief Engineer
- Full integration with on-shore logistics systems
- New Shore Control Centre, communication and connectivity

Research progress

From May to June 2023, a series of remote control and autonomous navigation technologies were demonstrated on the Eidsvaag Pioner feed carrier and the Zulu4 barge

JP-MEGURI2040

Facing domestic coastal shipping, leading in fully autonomous navigation demonstration and international standards

Demonstrators

- 2 coastal container ships
- Car ferry, large ferry
- Small amphibious boats, small tourist boats

Key Technologies

- Fully autonomous navigation and berthing and unberthing
- Multi sensor perception enhancement
- Shore based monitoring based on augmented reality
- Remote control and fault monitoring

Research progress

Complete **autonomous navigation tests for six ships** in 2022:

- Including autonomous navigation throughout the entire water area, autonomous berthing and unberthing, remote control

Starting the second phase in 2023:

- Continuing demonstration testing, standardization of completed technologies, research and development of infrastructure, and new generation ships suitable for future offshore shipping

KR-KASS

Korea Autonomous Surface Ship Project

Targeting the commercialization of large-scale autonomous ships for ocean going vessels, with the goal of expanding market share

Demonstrators

- Autonomous Ship Technology Test Ship
- Medium scale high-level independent demonstration ship

Key Technologies

- Advanced autonomous navigation, remote control, communication and cyber security, event response, and situational maintenance
- Autonomous Navigation in Complex Scenarios of Mesoscale Merchant Ship Testing
- Commercialization Model and Sales Strategy
- International Standardization System

Research progress

Build a 25m test ship in 2022

- Verification and evaluation of autonomous ship technology
- Obtaining and accumulating experimental data

CN (2020~2025)

Demonstrators

- Zhi Fei 300TEU
- Zhu Hai Yun research vessel

Zhi Fei

Zhu Hai Yun

Research progress

In the field of autonomous navigation, domestic efforts are mostly focused on small and medium-sized vessels and research vessels, with few demonstration applications in ocean going vessels and high-level autonomous navigation

Key Technologies

- Data integration
- Assisted decision-making
- Autonomous navigation in open water

CN（2020~2025）

ZhuHai → DaLian

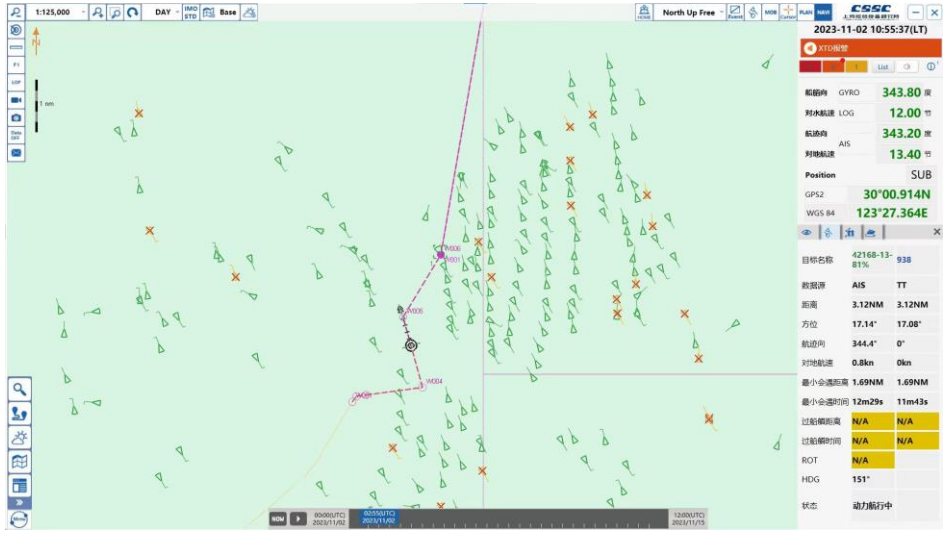
↖ ↙

ShangHai

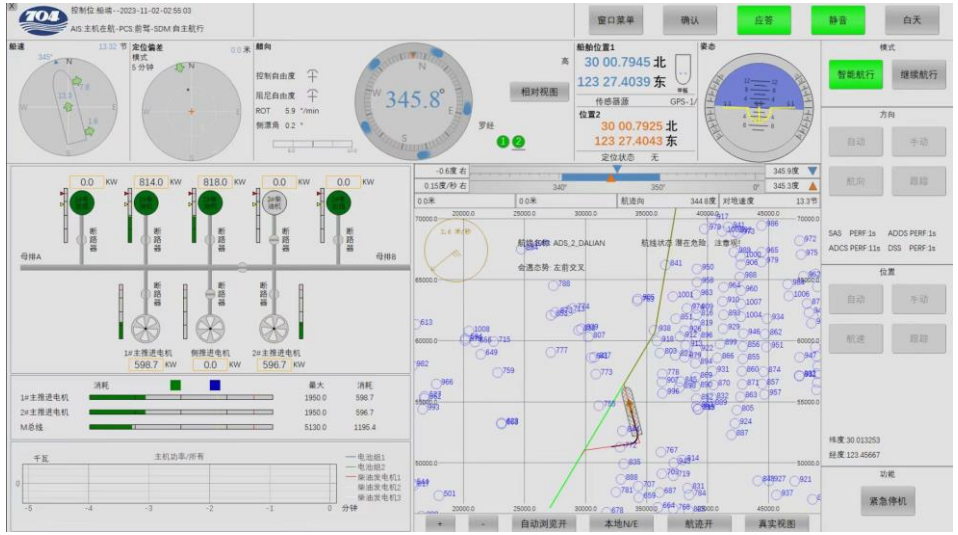
Total: 3000 nmiles

Passage through the most complex sea area for ships：The Pearl River Estuary, Taiwan Strait, Zhoushan Islands, Yangtze River Estuary, Yellow Sea and Bohai Sea.It took nearly 200 hours to complete more than 100 automatic collision avoidance

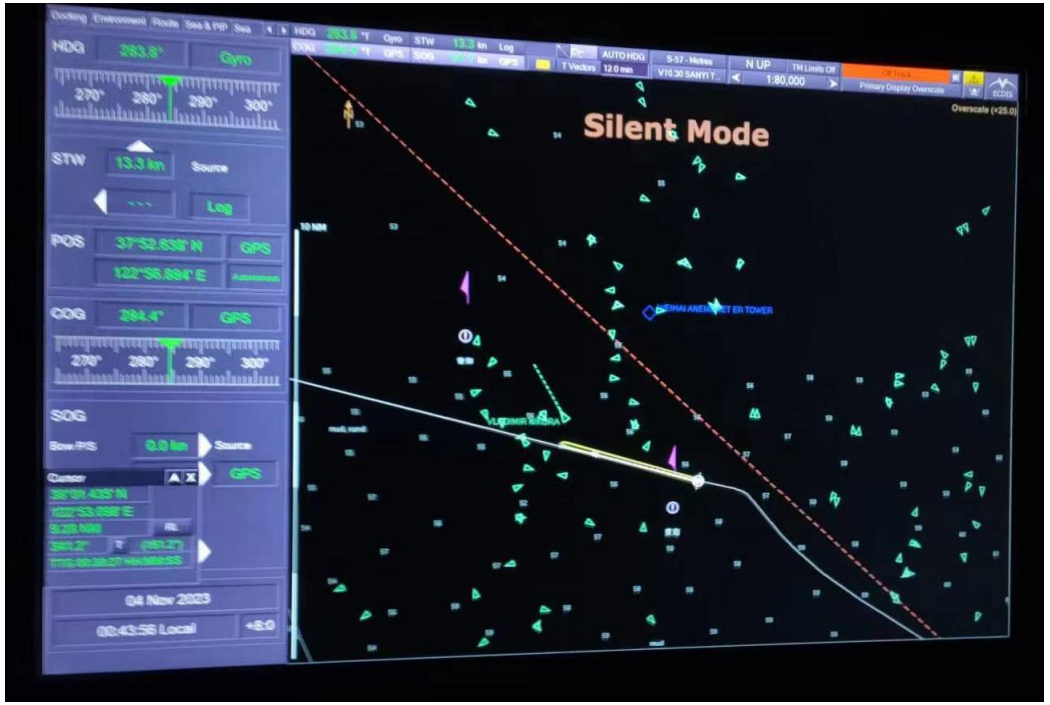
CN (2020~2025)



Zhoushan Islands(day)



Bohai Sea(night)



Main products for navigation

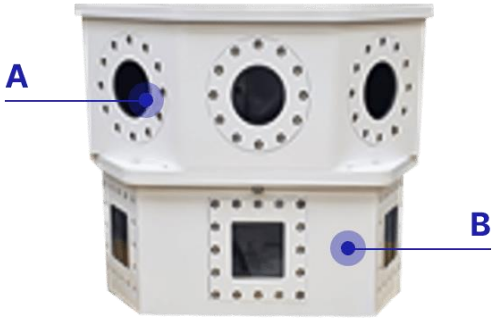
FURUNO

GROKE

Kongsberg

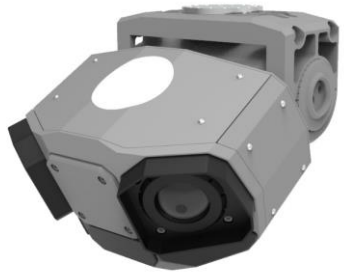
Orca AI

HiNAS



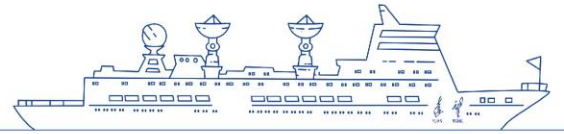
Seamachine

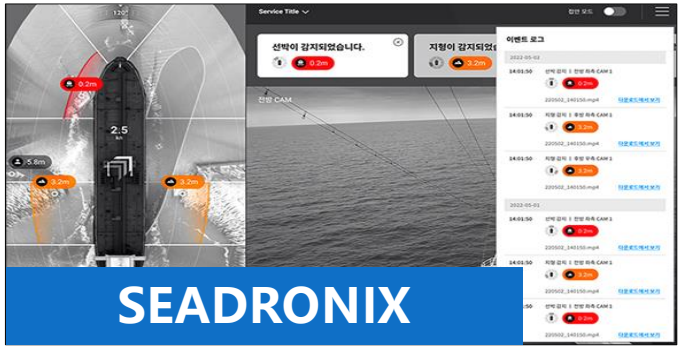
SEADRONIX

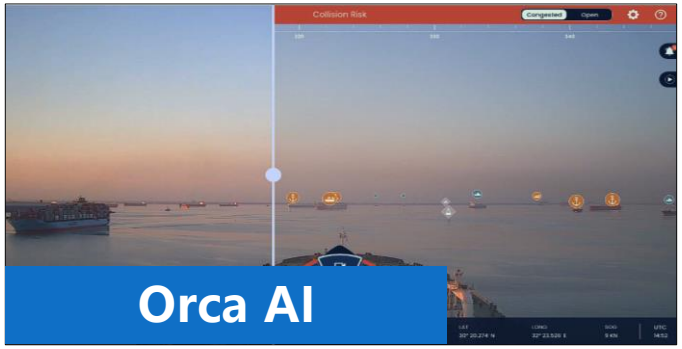


ABB

Main products for navigation



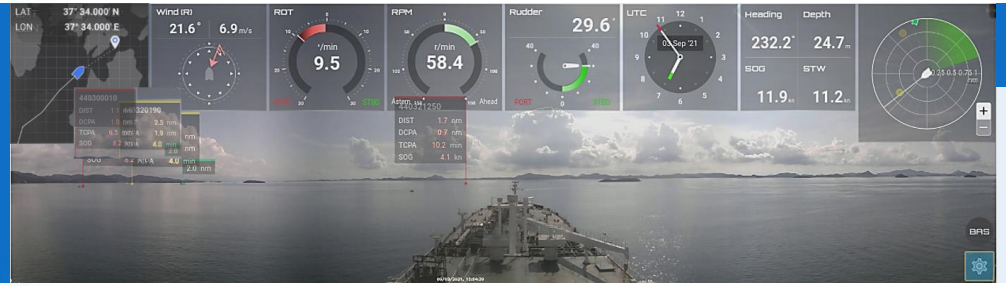




Typical Commercialization Case - Hyundai

Acquire European company Avikus and promote the commercialization of autonomous navigation technology vigorously

Avikus
MARITIME AUTONOMOUS PIONEER

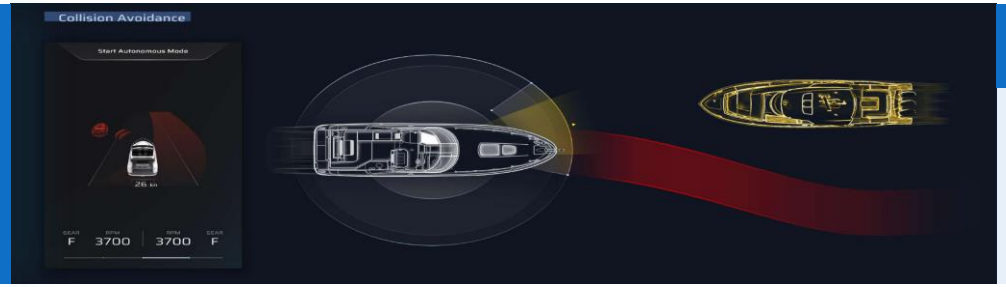


HiNAS -- Navigation Assistant System

- Multi sensor fusion perception • AR vision
- Autonomous navigation in open water (tracking+collision avoidance)

HiBAS -- Surround View Monitoring

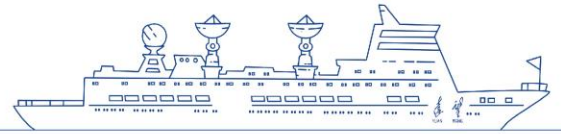
- 2D/3D panoramic camera stitching
- Distance monitoring and alarm



NeuBoat -- Autonomous Boat Solution

- Multi sensor fusion perception • AR vision
- Autonomous navigation in open water (tracking+collision avoidance)+autonomous berthing and unberthing

Future Work Priorities of MASS



Risk assessment

Ensure achievement of **a level of safety at least equivalent to** that expected of a conventional ship.

Verification & Validation

A key part of feasibility is knowing that the requirements can be verified
If V&V not in voluntary code, hard to introduce in mandatory code

Communication（between MASS and conventional ship）

All use collision avoidance rules, but in many scenarios there is a greater need for ship-to-ship communication，how to ensure communication between MASS and conventional ship, remotely operated ship

THANK YOU