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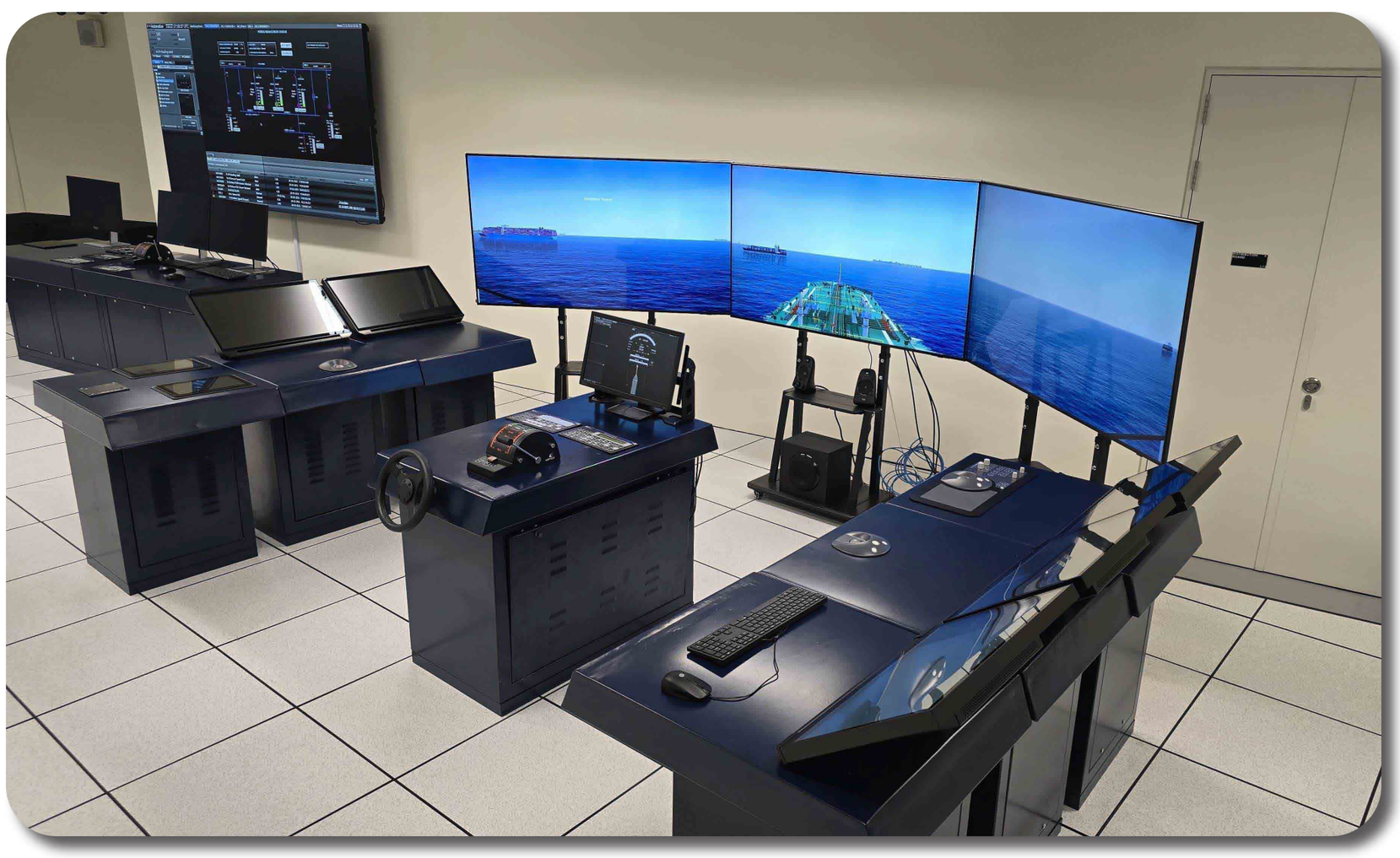
MINISTER'S INNOVATION AWARD

MPA SINGAPORE

MERIT AWARD

MARITIME TESTBED OF SHIPBOARD OPERATIONAL TECHNOLOGY (MariOT)



PROJECT TEAM

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IMPETUS FOR PROJECT

The maritime sector is grappling with significant and escalating cybersecurity challenges, particularly those impacting shipboard Operational Technology (OT) systems. In 2017, hackers seized control of a German-owned container ship's navigation for about ten hours, leaving the captain unable to manoeuvre until specialists restored the systems – a stark demonstration of safety and hijacking risk alongside operational delay. A key driver for the MariOT project is the growing concern over cyberattacks on shipping operations, amplified by the increasing digitalisation and enhanced connectivity between ship and shore-based systems. Cyber threats are continuously evolving and becoming more advanced, underscoring the critical need for robust preparation and defence mechanisms.

A major challenge identified is the difficulty in providing realistic, hands-on training for maritime personnel and cybersecurity professionals without excessive reliance on physical shipboard infrastructure. The industry needs to bridge the gap between theoretical cybersecurity knowledge and real-world operational challenges in detecting and responding to incidents. Simulated cyberattacks, such as the breaching of a ship's navigation system to alter its planned course and potentially cause collisions, illustrate the severe operational and safety risks at stake.

Therefore, the impetus for the MariOT project stems from the urgent need to upskill the maritime workforce, enhance industry resilience, and facilitate the development and validation of cybersecurity solutions against these growing and complex cyber risks.

Statement of Need:

The MariOT project is critically needed to establish a world-first, industrial-grade cyber-physical platform that provides a safe and realistic environment for strengthening shipboard cybersecurity training and accelerating the testing and validation of cybersecurity technologies, thereby enhancing the maritime sector's resilience against evolving cyber threats and ensuring the safety and security of global shipping operations.

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EXTENT OF INNOVATIVENESS

New idea/solutions

The MariOT project introduces a ground-breaking and globally unique approach to maritime cybersecurity training and technology validation. This is not merely a simulation; MariOT is a hybrid cyber-physical testbed that incorporates essential physical components of the shipboard OT systems, complemented by virtual simulation models and a cyber-physical interface. This unique combination allows for:

1) High-fidelity, realistic simulations: MariOT delivers unparallel realism, replicating key maritime systems such as navigation, propulsion, and power management. This design enables trainees to gain hands-on practice and experience with potential cyber threats in a controlled yet authentic environment, effectively bridging the gap between theoretical knowledge and real-world operational challenges.
2) Reduced reliance on physical shipboard infrastructure: It provides robust and rigorous cybersecurity training without the prohibitive costs and logistical complexities associated with using actual ships or their full-scale replicas.
3) Integrated training for diverse maritime stakeholders: Beyond traditional cybersecurity professionals, MariOT's capabilities extend to training seafaring crew by incorporating anomalous scenarios (like cyberattacks) into their operating environment, represented by physical component malfunctions and resulting system-level failures, thereby raising their situational and safety awareness in vessel navigation. This integrated approach is a novel method for comprehensive workforce development.

Response to new challenge

MariOT is a direct and unique response to the escalating and complex cybersecurity challenges impacting the global maritime sector, particularly within shipboard OT systems. The project addresses several critical emerging needs:

1) **Growing cyber risks from digitalisation**: The maritime industry is undergoing rapid digitalisation, with ships increasingly built with advanced digital technologies and interconnected Internet of Things (IoT) systems. While these innovations support sustainability and efficiency, they simultaneously increase cyber risk, making the sector more vulnerable to sophisticated threats. MariOT provides the necessary platform to proactively address these heightened risks.

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EXTENT OF INNOVATIVENESS

2) **Need for practical, real-world incident response training**: The maritime industry faces an urgent need to upskill its workforce to effectively identify and respond to evolving cyber threats. MariOT offers a safe, and controlled environment for maritime personnel (including ship crew, cybersecurity professionals, and port operators) to practice detecting cyber intrusions and executing appropriate incident response protocols. This hands-on experience is vital for future-proofing the workforce against cyber threats.

3) **Accelerating cybersecurity technology development and validation**: The facility serves as a practical platform for cyber solution providers to test and develop their solutions in a realistic maritime environment, enabling stress-testing of systems and the development of robust cyber defences. This significantly accelerates the pace at which new cybersecurity technologies can be validated and adopted within the industry, strengthening maritime operations' resilience against emerging threats.

4) **Advancing maritime cybersecurity research and global standards**: MariOT aims to explore collaborations with international partners to enhance simulation capabilities and contribute to the development of global cybersecurity standards, positioning Singapore as a leader in this critical domain.

Innovation Highlights:

MariOT's innovation lies in its status as the world's first industrial-grade cyber-physical platform, providing an unprecedentedly realistic and safe environment to bridge theoretical knowledge with practical, hands-on cybersecurity training and to accelerate the testing and validation of maritime OT defence technologies, uniquely equipping the global shipping industry to combat evolving cyber threats.

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IMPACT AND VALUE-CREATION

<u>Impact/Outcome</u>

The MariOT project delivers substantial impact across multiple dimensions, leading to significant gains in productivity, efficiency, and the development of critical new capabilities:

1) **Enhanced Cybersecurity Training and Competency Development:** MariOT provides high-fidelity simulations of essential shipboard OT systems that allows trainees to gain hands-on practice and experience with potential cyber threats, effectively bridging the gap between theoretical knowledge and real-world operational challenges. This directly upskills and reskills the maritime workforce, addressing growing cybersecurity challenges and future-proofing maritime operations. Over the next three years, we expect more than 300 students and professionals – including ship crew, cybersecurity practitioners, and port operators – to benefit from training and research conducted at this facility. This reflects Singapore's commitment to building a resilient workforce and advancing maritime cybersecurity through innovation, collaboration and education.

2) **Accelerated Technology Testing and Validation:** MariOT serves as a practical platform for cyber solution providers to test and develop their solutions in a realistic maritime environment. Researchers also benefit from a safe, and controlled platform to design and validate new and existing cybersecurity technologies.

3) **Operational Efficiency and Cost Savings:** By offering rigorous cybersecurity training and testing, MariOT reduces reliance on expensive and logistically complex physical shipboard infrastructure. This translates into substantial monetary and man-hour savings for training and development initiatives across the industry. Based on industry cost estimates, using MariOT in place of a physical vessel for a cybersecurity exercise can save approximately USD $26,000 per day, avoiding idle ship costs and opportunity losses. Furthermore, by strengthening industry readiness against cyber threats, MariOT helps mitigate disruptions and delays in ship operations.

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IMPACT AND VALUE-CREATION

Value-Creation/Human-centricity

MariOT is inherently human-centric, designed to directly address the pressing needs and challenges faced by diverse stakeholders withing the maritime ecosystem:

1) Addressing Workforce Needs and Challenges
   a. For Seafarers and Operational Personnel: The project directly addresses the challenge of providing realistic, hands-on experience in detecting and responding to cyber threats by simulating real-life scenarios, it provides a safe, and controlled environment for them to practice incident response protocols without endangering real assets or operations. This upskills and reskills them, making them more resilient and capable of navigating the digital transition in their careers.

   b. For Cybersecurity Professionals and IT Specialists: MariOT offers a platform to refine best practices, share expertise, and accelerate the testing of cybersecurity technologies, addressing their need for a collaborative and realistic environment to hone their skills.

2) Addressing Business and Industry Needs
   a. For Ship Owners, Port Operators, and Solution Providers: MariOT provides a practical testbed to validate and develop cybersecurity technologies against evolving threats. This addresses the need for robust cyber defences, helping businesses reduce their cyber risk, and maintain operational continuity.

3) Addressing Academic and Research Needs
   a. For Students: The integration of MariOT training into academic curricula enhances learning outcomes and provides clear pathways for specialisation in maritime cybersecurity, directly addressing their need for relevant, career-focused education.

   b. For Researchers and Educators: MariOT provides a platform for experiments and development of manpower capability, addressing their need for research and development purposes.

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IMPACT AND VALUE-CREATION

Engagement in the Process and Inputs Shaping the Solution
MariOT's design and development are deeply rooted in collaborative engagement with its intended users and partners:

- Collaborative Development: MariOT was developed in close collaboration with the Singapore University of Technology and Design (SUTD) and industry partners and supported by the Singapore Maritime Institute (SMI). This foundational partnership ensured that the platform was built with industry relevance and practical needs at its core.

- Fostering a Collaborative Environment: MariOT is designed to foster a collaborative environment where diverse professionals – engineers, IT specialists, and maritime personnel – can share expertise and refine best practices. This continuous interaction allows for direct input and shaping of training scenarios and technological evaluations.

- Academic and Research Partnership: MPA plans to integrate MariOT training scenarios into academic curricula through partnerships with Institutes of Higher Learning and SMI leading research initiatives at the facility. This direct engagement with academic institutions and researchers ensures that the platform evolves based on educational and research requirements.

- International Collaboration: The exploration of collaborations with international partners aims to further enhance simulation capabilities and contribute to global cybersecurity standards development. This broadens the base of expertise and ensures the solution addresses global maritime challenges.

Outcome:

MariOT significantly elevates maritime cybersecurity capabilities by providing a world-first, industrial-grade cyber-physical platform that enhances hands-on training, accelerates the validation of critical defence technologies, and reduces operational disruptions, ultimately strengthening industry resilience and securing global supply chains through a collaborative and human-centric approach.

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FEASIBILITY AND SCALABILITY

Feasibility

MariOT demonstrates strong feasibility, underpinned by its current operational status, robust technological foundation, and established collaborative partnerships:

1) **Operational and Commissioned:** MariOT is not a conceptual project but an already commissioned and operational industrial-grade cyber-physical platform. This confirms its immediate achievability and practical execution.

2) **Proven Technology and Design:** It features high-fidelity simulations of power and propulsion systems and navigation systems onboard an oil tanker using actual protocols that are certified by classification society, DNV. This emulation allows for launching various cyber-attacks and validating detection and defence mechanisms as in a real system. This demonstrates the effective application of current and near-future technologies.

3) **Established Partnership and Committed Resources:** MariOT was developed in close collaboration with SUTD, SMI and industry partners. This extensive network of academic and industry expertise, coupled with backing of MPA, ensures the necessary technical and human resources are in place for its ongoing operation and development.

4) **Practical Application and Training:** MariOT is actively used for training students and professionals including ship crew, cybersecurity professionals, and port operators. It was used to support a cybersecurity technical exercise involving international and domestic maritime organisations in March 2025. International and local maritime operators and cybersecurity practitioners will participate in the MariOT cybersecurity technical exercises. MariOT has been identified to be included as a critical infrastructure testbed for SAF/DIS annual Critical Infrastructure Defence Exercise (CiDEX). It also serves as a practical platform for cyber solution providers to test and develop their solutions in a realistic maritime environment, which is a safer and more cost-effective alternative to testing on physical shipboard infrastructure.

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FEASIBILITY AND SCALABILITY

Scalability

MariOT possesses significant scalability and potential for cross-domain adaptation particularly given its core focus on cyber-physical systems and OT:

1) **Continuous Capability Expansion:** MPA and its partners are committed to continuously expanding MariOT's capabilities to address evolving cyber threats and to conduct regular training exercises. This inherent design for growth ensures its long-term relevance and capacity to scale within the maritime domain.

2) **Integration into Academic Curricula:** MPA plans to integrate MariOT training scenarios into academic curricula for maritime-related courses through partnerships with Institutes of Higher Learning. This systematic integration offers a scalable pathway for developing specialised manpower in maritime cybersecurity across the education sector.

Cross-Domain Applicability (Operational Technology Focus)

1) MariOT's design for OT security makes its underlying principles highly adaptable to other critical infrastructure sectors. OT systems are prevalent in aviation, and land transport sectors. For example, MariOT's power and propulsion system emulate the diesel engine of an oil tanker and sectors that use diesel engine can make use of it to test solution or train their engineers in cyber threat against such power systems.

2) The methodology of providing high-fidelity simulations for hands-on practice, testing incident response protocols can be directly applied or replicated to create similar testbeds for OT security training and research in non-maritime domains.

Potential of Project:

MariOT demonstrates immediate practical execution in upskilling professionals and students and validating cybersecurity solutions within a realistic environment, while possessing significant growth potential through continuous capability expansion, integration into academic curricula, and the development of global cybersecurity standards, making its core methodology highly adaptable for critical OT security applications.