Integrating Multi-Domain Operations (MDO) into Maritime Interdiction:

How NMIOTC is transforming into an MDO-Focused Training Centre

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Mastering the Maritime Environment

This series of position papers explores the evolution of Maritime Interdiction Operations (MIO) through the integration of Multi-Domain Operations (MDO). Traditionally, MIO has relied on conventional methods such as boarding, searching, and seizing vessels based on limited intelligence. However, MDO enables a more sophisticated and efficient approach by leveraging space-based surveillance, cyber capabilities, artificial intelligence (AI), and autonomous systems. Part three of this paper is a general discussion with Commodore Piyis surrounding the future of Maritime Interdiction Operations, Maritime Security, and how an advanced naval unit, capable of conducting MIO can adapt to meet today's emerging threats.

Commodore (OF-6) Periklis PIYIS, Hellenic Navy Commandant NMIOTC

Commodore Periklis Piyis graduated from the Hellenic Navy Academy in 1991 as a warfare officer.

He has served on several surface units of the Hellenic Navy and had the honor to command two ships during his career;

Ashore, he was assigned for a total of 10 years at the Hellenic Navy General Staff (HNGS), as Head of the Weapons and Ammunitions Department, Director of Surface Programs at the Armaments Directorate, Head of the Guided Missiles and Electronic Warfare Systems Department, and finally Director of C3, Weapons and Electronic Warfare Systems Directorate.

He has multifaceted experience working on NATO programs and with NATO organizations. Notably, he was assigned from May 2010 – July 2013, as a Fire Control Systems Engineer at the NATO Sea Sparrow Office (NSPO) in Den Helder, The Netherlands. From May 2020 – June 2021, he was the National Representative to the executive meetings of the NATO Sea Sparrow Program and the National Representative to the NATO Naval Armaments Directors meeting. From June 2021-Sep 2022 he served as BH of the Strategic Partnerships Branch at NATO HQ SACT (Norfolk, Virginia) assigned in parallel as the team leader for developing and promoting the Layered Resilience Warfare Development Imperative. From Sep 2022-Aug 2024 he was assigned as BH of the Warfare Development Fusion (WDFB) Branch responsible for the implementation of the NATO Warfighting Capstone Concept (NWCC). From Sep 2024 – January 2025 he was assigned as COS of the NATO Maritime Interdiction Operational Training Centre (NMIOTC). Since January 2025, he has served as the Commandant of NMIOTC.

He has graduated from both the Hellenic Joint Supreme War College and the Hellenic Defence College. He has also attended the MSc in Shipping and Transport programme, at the Rotterdam's Maritime University.

Q: What is your assessment of global maritime security?

A: The current state of global maritime security is shaped by a variety of factors and metrics. I would say that there are seven primary threats to stability in the maritime environment, stemming from geopolitical, economic and environmental factors. In random order;

First is **piracy and armed robbery** which stems from economic and geopolitical instability in certain regions. Thankfully, piracy and armed robbery is decreasing in regions that were previously notorious. Incidents in hotspots like the Gulf of Aden and the Indian Ocean have significantly decreased in recent years. In 2008, the year of NMIOTC's formation, piracy in these regions were at an all-time high and were of great concern to NATO members and partners. However, over the years, through concerted efforts with partners and allies, these previously known hotspots are no longer the threats that they once were. That being said, incidents of piracy and armed robbery in other regions of the world are persisting or increasing. The Gulf of Guinea, Southeast Asia (the Sulu-Celebes Sea) and parts of the Caribbean remain as regions afflicted by acts of piracy. We have had the privilege of working with Boarding Teams from NATO countries who are deeply involved in preventing acts of piracy in these regions, such as the Dutch Fleet Marine Squadron.

The second threat to maritime security is **geopolitical tensions**. Territorial disputes among countries world wide have led to heightened naval activity, raising risks of conflict in geographical areas which include some of the world's busiest trade routes. Melting ice opens new shipping lanes, leading to competition for resources and strategic position by Arctic and interested nations. Ongoing conflicts, including the war in Ukraine, have disrupted maritime trade routes, especially for energy and agricultural exports. MIO, as outlined by NATO, is an inherently peace time mission set. However, there is always the possibility of these operations increasing geopolitical tensions between countries which poses a significant challenge when attempting to enforce rules and norms.

Linked closely with geopolitical tensions is the concern of **climate change and environmental challenges**. Rising sea levels and storms are becoming increasingly more severe which disrupt shipping lanes and port infrastructure. Illegal, unreported and unregulated (IUU) fishing remains a persistent threat to maritime ecosystems and coastal economics, especially in the Pacific and Indian Oceans. The threat of famine from climate change presents the possibility of piracy in coastal regions where plundering of passing merchant traffic is the only means of survival. As the climate continues to change, climate refugees will become an issue that will affect maritime security.

Emerging threats to **cybersecurity** also play significant roles in global maritime security. Maritime infrastructure and vessels are increasingly reliant on digital systems, making them vulnerable to cyberattacks. Incidents targeting ports, shipping companies, and navigation systems have highlighted the sector's vulnerability to sophisticated threats.

Terrorism and smuggling has been and will continue to be a persistent threat. Smuggling of weapons, drugs, and people remains a key maritime security concern and one that NMIOTC actively seeks to combat. Hotspots in the Mediterranean, the Andaman Sea, and the Gulf of Aden pose significant threats to NATO allies and partners. Maritime terrorism, though less frequent, remains a risk, with threats to energy infrastructure like pipelines and oil tankers. Critical underwater infrastructure (CUI) is likely to be the 21st century's prime target of both non-state and state sponsored terrorism due to our increased reliance upon undersea cables and pipelines.

Increased **naval militarization** in strategic waterways like the Indian Ocean, Pacific Ocean, and Eastern Mediterranean fuels concerns over freedom of navigation and security of trade routes.

Lastly, **coordination and governance** has, by and large, been a net gain in terms of maritime security. Efforts to improve maritime security governance have advanced through initiatives like the Djibouti Code of Conduct, Combined Maritime Forces (CMF), and regional frameworks like ASEAN's counter piracy initiatives. However, challenges persist due to varying levels of commitment, capacity and coordination among nations.

In conclusion, while there have been significant strides in reducing piracy and enhancing regional maritime collaboration, emerging threats such as geopolitical tensions, climate change, cyber risks, and the persistent challenges of IUU fishing and smuggling demonstrate the evolving nature of maritime security. A multi-stakeholder approach that incorporates international cooperation, technology, and adaptive strategies is critical to addressing these challenges effectively.

Q: How important do you assess the application of MDO principles in MIO?

A: MIO are a strong and existing example of MDO in practice. However, MIO could evolve for better integration with MDO . Some key practical areas where MIO can adapt or expand to become a more effective expression of MDO principles are:

Enchanced Real –Time Multi Domain ISR integration

MIO often relies on maritime and air ISR with limited integration of cyber and space domains in real-time. The fusion of ISR from Space, UAVs, MPAs and Cyber into a common operational picture, as well as, the employment of AI for data fusion across domains will enable faster and more accurate interdiction targeting.

Cyber Operations as a standard component

Cyber effects are not typically embedded into MIO planning. The integration of offensive and defensive Cyber operations into MIO task forces and the use of Cyber tools to preemptively disable or track suspect vessels will enhance proactive interdiction capabilities and expand capabilities for non-kinetic influence.

AI and Predictive Interdiction

Interdiction is largely reactive, based on known ship movements or intelligence information. The use of AI/ML to analyze shipping patterns, financial transactions and intelligence as well as the automation of threat prioritization and route anomaly detection will shift MIO from reactive to predective, alligning with MDO's emphasis on decision dominance.

Common MDO – Capable C2 Architecture

C2 systems for MIO are often stovepiped. The adaptation of all domain C2 compatible systems that allow fluid, cross-domain tasking and asset sharing will lead to true interoperability and faster cross-domain operational coordination.

Q: Do you forsee MIO becoming more prominent and relevant in the near future to address maritime security issues?

A: Threats related to piracy, smuggling, and illicit activity in the maritime environment will always necessitate a MIO infrastructure, whether it be national or coalition led. The inherent benefits of MIO; deterrence, collaboration and resilience, will always exist. The visible presence of MIO forces deters potential offenders. MIO fosters international cooperation, as many operations are conducted by coalitions or under international mandates (i.e., NATO, EU NAVFOR, CMF). It bolsters the resilience of maritime nations by protecting their economies, natural resources, and populations from threats. However, MIO has yet to fully define its role in combating emerging threats to cybersecurity and critical underwater infrastructure. These two "threats of the future" certainly necessitate MIO involvement but to what extent remains to be seen. Established and emerging MIO assets have the unique opportunity to further solidify their own relevance by embracing technologies that enhance their capabilities. The implementation of Maritime Unmanned Systems (MUS) allows for force multiplication as well as greater protection.

Commodore Piyis addressing the students of Course 25000, "Drafting, Production & Maintenance of NATO Standards.

Q: What are the most pressing challenges that MIO/boarding teams face today in enforcing maritime laws and preventing illicit activity?

A: Today's most pressing challenges to MIO are the legal complexities, resource limitations and adaptability of threats. Boarding and seizing vessels require strict adherence to international maritime law and sovereignty of states. These challenges can be overcome by clear and concise understandings of the legal requirements as well as the incorporation of legal experts into the boarding teams themselves. Effective MIO requires significant resources, including advanced technology, well-trained personnel and naval assets. Often times, incorporation of technology into the tactics and procedures of MIO remains untested with little opportunity for experimentation. NMIOTC seeks to bridge this gap in the coming years by providing teams an environment to test their TTPs in conjunction with advanced technology (i.e., MUS, wearable AI) in a controlled environment. Due to many national requirements, access to the technology remains behind a "policy wall" which requires delicate legal navigating. This challenge can only be overcome on a nation-by-nation basis. Lastly, criminal and terrorist networks constantly adapt to avoid interdiction, requiring ongoing innovation in tactics and technology. An example of this is the increasingly advanced narco-subs that are being interdicted in and around the Caribbean. With ample resources, criminal networks are able to adapt their own tactics and materials which must be observed, reported and countered for MIO teams to remain relevant.

Q: What operational gaps do boarding teams experience in terms of equipment, training, or interoperability?

A: The operational gaps experienced by boarding teams vary depending upon the mission, capability and operating environment of the team. For instance, conventional boarding teams that perform embargo and customs enforcement are rarely conducting opposed boardings. Therefore, the operational gaps they face are far different than those of teams that carry out counter-terrorism or counter-piracy operations in hostile environments. However, due to the nature of the maritime environment, certain challenges will always present operational gaps.

Equipment

Limited functionality of communication equipment due to environmental factors and shipboard conditions will always be an issue. Adequate communication equipment is difficult for teams to procure and they often resort to alternate and contingency methods of communication. As adversaries evolve, teams are often ill-equipped to detect threats in the pre-boarding phase. A lack of unmanned system capabilities or availability for pre-boarding reconnaissance poses a significant risk to MIO assets. Additionally, inadequate scanning equipment, limited access to portable X-ray machines or handheld scanners for detecting contraband in concealed spaces introduces the opportunity for inefficient MIO employment.

Training

In terms of training gaps, many teams do not have access to scenario based training. Teams may lack experience in dealing with non-compliant or opposed crews, particularly those using force or deceptive tactics. Additionally, teams don't have access to complex vessel types and there is insufficient training for operations aboard non-standard vessels such as oil tankers or high speed craft. NMIOTC has taken great pains to build a library of complex and dynamic scenarios for teams to test their tactics, decision making, and planning processes. We also are equipped with a number of training platforms that present different environments for teams to train in. But we are only one training provider and not every NATO MIO team has the opportunity to train here due to their own national budgeting obligations. Lastly for training gaps, MIO assets might lack cultural and legal training. This limited understanding of cultural norms and practices, can escalate tensions during inspections. There is also inadequate knowledge of international maritime law, which can lead to operational missteps or unintended violations of sovereignty. NMIOTC seeks to bridge this gap by providing courses in both legal as well as gender/cultural aspects, during the conduct of MIO. By teaching courses on gender/cultural aspects, we do not seek to promote a specific societal understanding of gender, but to instead promulgate those principles laid out in the UN Universal Declaration of Human Rights (UDHR).

Interoperability

Interoperability gaps exist in Command and Control (C2), multinational coordination and joint training exercises. Information sharing is a key element of interoperability. Real-time data exchange between boarding teams and command centers is often delayed or unreliable. Equipment incompatibility (i.e., communication systems, sensors) between coalition partners can disrupt coordination. This issue will only be further exacerbated by the implementation of Maritime Unmanned Systems. A common operating picture, promulgated from the Boarding Team all the way to the MIO Commander will become even more unattainable if more sensors are included in the boarding operation without significant advances in information sharing. Differing boarding procedures, rules of engagement, and TTPs across nations create delays and confusion during joint operations. NATO doctrine, specifically ATP-71, seeks to mitigate this operational gap but it remains outdated and ineffective against modern threats. Lack of multilingual capabilities can also hinder coordination between boarding teams and foreign vessel crews. Lastly, infrequent joint drills between NATO members and partners leads to limited opportunities, lack of familiarity and cohesion among multinational assets.

Q: How have recent technological advances such as ISR, Drones, and AI impacted the success of MIO? Can you describe any recent MIO missions that have set a new benchmark for success or highlighted areas to improve and develop in MIO tactics?

A: There are a number of recent technological advances that have either directly impacted the success of MIO or have the potential to if embraced by MIO training programs:

Improved Situational Awareness

Advanced surveillance systems such as UAVs, satellite imagery, and maritime radar systems have all aided in enhancing the situational awareness of MIO assets. Drones have provided real-time reconnaissance and surveillance, allowing boarding teams to assess vessel activity and layout before boarding. High-resolution satellite systems enable the monitoring of vast maritime areas, tracking vessel movements, and identifying suspicious activity. Modern radar systems, such as Synthetic Aperture Radar (SAR), detect and track vessels even in adverse weather, at night or far over the horizon. AIS has been around for a long time and has been a reliable source of intelligence to MIO assets. Now Big Data and AI algorithms can analyze AIS data, historical patterns, and vessel behaviors to flag potential threats before physical interdiction is required.
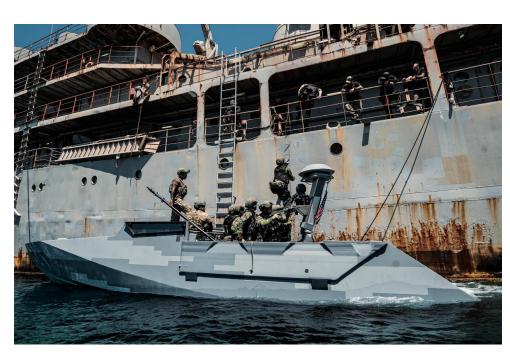
Enhanced Safety Measures for Boarding Teams

Advanced Personnel Protective Equipment (PPE), including lightweight ballistic armor and helmets, protects teams without restricting mobility. Fire-resistant and chemical-resistant suits protect against hazards in environments involving hazardous material. Simulated training environments have the potential to revolutionize the ways that boarding teams train. Using Virtual Reality and Augmented Reality, boarding teams can train in realistic, simulated environments, preparing them for high-pressure scenarios while reducing training risks.

Enhanced Boarding Team Capabilities

Robotics and automation are being incorporated into boarding team capabilities through unmanned surface vehicles (USVs) and robotic boarding devices. USVs can perform initial inspections or act as deterrent platforms, reducing risks to boarding personnel. Mechanized systems assist in climbing onto vessels, especially those with high freeboards, reducing the physical limitations and danger to teams (see Singapore Coast Guard Spyder). Advanced detection tools have always been a need for boarding teams, especially those going into CBRN environments. As mentioned before, handheld X-ray scanners and chemical detection tools help locate contraband. Biometric Identification tools have supported MIO for many years as well.

Better Command and Control Integration

As mentioned before with operational gaps, C2 is a serious need in cooperative Maritime Interdiction Operations. However, technology exists to help mitigate those gaps through real-time communication technologies and networked operations. Secure, high-bandwidth communication systems (i.e., satellite communications, encrypted networks) enable seamless coordination between boarding teams, command centers, and supporting naval assets. Command centers can provide live updates, monitor team locations, and direct operations based on changing conditions. Interoperability platforms connect coalition forces, enabling the sharing of intelligence and operational data. Tools like NATO's Federated Mission Networking (FMN) enhance coordination among multinational forces.

Q: How have recent technological advances such as ISR, Drones, and AI impacted the success of MIO? Can you describe any recent MIO missions that have set a new benchmark for success or highlighted areas to improve and develop in MIO tactics? (continued)

Countering Evasive Tactics

Underwater threat detection and vessel stopping technologies provide even greater capabilities to boarding teams through sonar and submersible drones, mine detection systems and non-lethal vessel stopping systems. Detecting hidden compartments, waterline threats, or explosives can be done by submersible drones that are deployed in the pre-boarding phase. Technologies that target machinery rather than personnel like entanglement nets, directed energy weapons, or electromagnetic pulses (EMP) can disable non-compliant vessels without causing permanent damage or inflicting harm on its crew members.

Increased Success in Disrupting Illicit Activities

Through AI and ML, boarding teams can have increased capabilities when carrying out the administrative portions of onboard actions. AI-powered systems analyze shipping manifests, crew lists, and cargo declarations to flag discrepancies and identify high-risk vessels. Machine learning algorithms improve the accuracy of threat prediction, enabling preemptive interdiction. Block chain technology is being used to validate the authenticity of shipping documentation, reducing the chances of smuggling or fraudulent declarations.

Q: What emerging threats or trends could complicate MIO in the next decade?

As mentioned before with the emerging threats coming from cyberattacks and asymmetric warfare tactics that target critical underwater infrastructure, MIO will be force to evolve to meet these and other threats:

Increased Use of Unmanned Surface and Subsurface Vehicles

Smuggling operations and acts of terrorism that incorporate autonomous or remotely operated vessels on and below the surface will likely become a serious threat of the future and will make detection much more challenging. Boarding teams might struggle to interdict unmanned vessels as traditional tactics like boarding and inspecting will not apply. Incorporation of sonar systems will be necessary.

Advanced Cyber Security Threats

As mentioned before, port infrastructure and communication flow between MIO assets are already targets of cyberattacks. Safeguarding these networks will be a critical necessity.

Proliferation of Submersible Vessels

The increasing use of semi-submersible or fully submersible vessels for smuggling poses a serious challenge to MIO. These vessels are harder to detect and traditional boarding operations may be ineffective against them.

Expansion of Hybrid and Asymmetric Warfare Tactics

Non-State actors and terrorist organizations post a significant threat to MIO as they continue to expand and evolve. MIO teams may face more complex scenarios involving disguised or "false flag" vessels, which deliberately misrepresent their identity or cargo. These tactics can complicate interdiction decisions, making it difficult to distinguish between legitimate shipping and threats.

Q: What are the biggest training or operational deficiencies you've observed in boarding teams globally?

A number of training and operational deficiencies exist globally and have been aggregated through collection of after action reports and open source intelligence.

Training Deficiencies

> Scenario-Based and Realistic Training
> Legal, Cultural, and Rules of Engagement (ROE) Training
> Cybersecurity and Technological Proficiency
> Medical and Trauma Response

Operational Deficiencies

> Communication and Interoperability
> Equipment and Technological Shortcomings
> Coordination and Standardization

Q: What new platforms, equipment, or training do you think boarding teams will need to remain effective in the future? What has become ineffective or obsolete?

A: The complexities of the modern maritime environment, coupled with the emerging threats of the future necessitate a range of new platforms, equipment and training methodologies. These adaptations are aimed at addressing the risks that are inherent in MIO while also tackling the needs of the future:

New Platforms

The importance of incorporating unmanned systems, surface and aerial vehicles, cannot be stressed enough. UAVs and USVs offer enhanced surveillance and reconnaissance while reducing personnel risk. Autonomous underwater vehicles that are capable of sub-surface threat detection and environmental monitoring can help boarding teams of the future meet the evolving threats. Lastly, integrated command and control platforms bridge the gaps between operator and control center. Data fusion centers and AI-enhanced analytics can leverage machine learning to provide a comprehensive operational picture.

Obsolete Platforms

Legacy Command and Control Systems that are non-networked and isolated are becoming increasingly inadequate and will soon only be effective as secondary and tertiary systems. The future need is modern, integrated, real-time, multi-domain situational awareness which can ingest data from satellites, UAVs, and other sensor platforms. These "digital battlespaces" allow for faster decision-making and dynamic mission adjustments.

Conventional patrol vessels without integrated sensor suites, sonar, modern radar and automated identification systems are less effective in detecting agile or stealthy threats. There will always be a need for low-risk, low-intensity MIO that is relegated to certain missions. But that is not the future of the mission set and is ineffective at meeting evolving threats.

Advanced Equipment

As mentioned previously, next-generation Personnel Protective Equipment (PPE) that offers lightweight protection and environmental adaptability will help the teams of the future to perform MIO in all locations. Incorporating non-lethal and less than lethal systems help to stop non-compliant suspect vessels, restrain suspects and breach into fortified positions without exposing the team to risk and avoid crossing diplomatic redlines by minimizing casualties. Enhanced communications and sensor systems provide secure, real-time communications and greater situational awareness and an ability to quickly and non-invasively detect contraband hidden in vessel compartments.

Obsolete Equipment

Non-digital communication devices, traditional analog radios and unsecured communication networks are vulnerable to interception and interference, hindering secure coordination. The need is encrypted, high-bandwidth communication systems that support seamless interoperability across multiple units and allied forces.

Outdated surveillance and reconnaissance tools that rely merely on optical and radar systems do not provide MIO teams with the tools necessary to create an effective common operating picture in the modern maritime environment. Upgraded sensors, including Synthetic Aperture Radar, multi-spectral imaging and unmanned systems will provide the precision needed for modern MIO.

Manual breaching and boarding equipment continue to limit boarding team's capabilities and place undue risk on the team during the very vulnerable insertion phase. If teams wish to remain relevant, advanced and adaptable; remote and robotic systems that that minimize human exposure during boarding operations should become standard.

Reliance upon paper records and legacy electronic systems for shipping documents is prone to errors and tampering. Block chain based documentation and real-time digital ledger technologies can enhance transparency and authenticity in cargo and vessel data management.

Enhanced Training Programs

Cybersecurity and digital literacy will be a keystone of future MIO. Given the increasing reliance on digital platforms and data fusion, training boarding teams to understand and manage cyber threats is critical. This includes securing communication devices and understanding the basics of digital forensics and data integrity. Interoperability drills that bring together forces from various nations and agencies to improve standardization of procedures, language skills, and cultural competencies will greatly enhance boarding team's capabilities in the future. Lastly, integrating current CQB tactics with advanced technological systems (i.e., wearable AI, advanced communications, next gen PPE) must be seamless and can only be achieved through adaptive tactical training. Counter-terrorism necessitates close-quarters maneuvers, rapid decision making, and dynamic response techniques tailored to maritime environments. The role of advanced technology must be understood and incorporated to seamlessly into these necessities.

Final Words from the Commandant

Q: How can an advanced NATO naval unit improve their contributions to global maritime interdiction efforts?

A: NATO Member States with advanced naval capabilities and a desire to improve are in a unique position to help bridge the operational gaps that exist in MIO globally. There are four primary ways to do this:

Invest in Modern Equipment

Provide boarding teams with state-of-the-art tools, PPE, and communications systems. By leading the way in embracing, incorporating and implementing new technology into MIO, NATO members can be an alliance leader in development of doctrine and tactics.

Enhance Training Programs

Focus on scenario-based, cross-cultural, and advanced tactical training tailored to diverse maritime environments. Working hand-in-hand with NMIOTC, using our platforms, our role-players and our experience, teams can help develop a robust training curriculum that can be promulgated to all of NATO.

Improve Interoperability

Develop standardized boarding protocols, conduct joint training exercises and ensure compatibility of equipment among coalition forces. In doing so, the operational gaps in C2 and the lack of common operating picture become benign.

Leverage Technology

Incorporate MUS, AI-powered surveillance, and real-time data-sharing platforms to enhance situational awareness. Working with national level policy makers, seek to cultivate relationships with industry and academia to procure the most effective technology and develop the most advanced tactics as a result.

He Who Commands the Sea has Command of Everything

- Themistocles

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