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Operational Analysis and CONOPS Definition for Next Generation Mine Warfare

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OPERATIONAL ANALYSIS AND CONOPS DEFINITION FOR NEXT GENERATION MINE WARFARE

EXECUTIVE SUMMARY

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Project Summary

This project conducted operational effectiveness analysis to inform future operational concepts for mining. It defined candidate operational concepts for mining operations with a focus on capabilities and associated design requirements. It developed architectural representations of mining operations to highlight the operational activities and systems associated with mining operations and define the system design decisions (e.g., platforms, manning) that contribute to the operational effectiveness of minefield deployment. The project developed and analyzed an agent-based simulation model using the Modeling and Simulation Toolbox (MAST) feature of the Orchestrated Simulation through Modeling (OSM) framework developed by the Naval Surface Warfare Center, Dahlgren Division. The OSM MAST model was used to compare airborne, surface, and subsurface deployment strategies as well as the key performance drivers (in terms of operational activities, hostile behavior, and system design decisions) that drive operational effectiveness. Analysis demonstrated that hostile posture (defined in terms of enemy detection capability and probability to change course upon mine detection) had a larger impact on minefield effectiveness than any characteristics of the minefield, individual mine characteristics, or deployment vessel. Additional analysis was conducted on operational and design characteristics of deployed minefields which found that the quantity of the mines in the minefield had a larger impact than individual mine characteristics or deployment vessel. An isolated analysis of alternative deployment strategies found that, in general, airborne deployment vessels outperformed both surface and subsurface deployment strategies.

Keywords: o*ffensive mining, agent-based simulation, operational effectiveness analysis, model-based systems engineering*

Background

Naval mines are responsible for the sinking of more ships since World War 2 than any other weapon type. In a 1977 article in the United States Naval Institute (USNI) *Proceedings*, RADM Roy F. Hoffmann stressed the historical impact that mining operations have had throughout United States Navy conflicts, from the American Civil War through World Wars 1 and 2 to conflicts in both Korea and Vietnam (Hoffman, 1977). RADM Hoffman emphasizes that naval mining has historically played a prominent and effective role in warfare and creates an asymmetric advantage for the employer. In 2018, the same ideas were expanded, also in USNI *Proceedings*, by ADM James Winnefeld and Captain Syed Ahmad (2018). In their article, they note that while US naval mining capability has atrophied in recent years, there is immediate opportunity to expand the capabilities of the US Navy through development and analysis of mining operations. Specifically, there are opportunities for advancement in mining operations that span communications, machine intelligence, command and control, detection, lethality, signature reduction, modularity, endurance, and reliability. Development of mining capability requires investigation of the systems responsible for the deployment, monitoring, and recovery of naval mines at the early stages of system development.

Recent efforts in mine warfare have resulted in increased interest and emphasis on surface and subsurface platform support for offensive mining. Previous studies and analyses have focused primarily on the employment of minefields and their resultant effects, with little regard to the impact of the mine delivery platform's resultant unavailability to the joint operation. Accordingly, they have focused on isolated examination of minefield deployment and characteristics. This research expands previous efforts by examining alternative unmanned and manned systems of systems capable of deploying and supporting minefields as an integrated part of joint offensive operations. Specifically, it considers multiple candidate operating areas and alternative delivery platforms.

This project utilized quantitative analysis, supported by development of Lifecycle Modeling Language–compliant model-based systems engineering (MBSE) products and associated agent-based simulation models, to examine the scalability of minefield deployment and support. The modeling and analysis effort is summarized in Deken et al. (2021). The modeling effort was conducted in the Modeling and Simulation Toolbox (MAST) feature of the Orchestrated Simulation through Modeling (OSM) framework developed by the Naval Surface Warfare Center, Dahlgren Division. Use of OSM MAST enabled assessment of alternative delivery platforms (e.g., airborne vs. surface) using appropriate use cases for each platform. This analysis also assessed the impact that development of new classes of mines (e.g., smart mines) may have on the determination of appropriate delivery platforms. Student involvement focused on development of both the MBSE products and MAST models within OSM.

Findings and Conclusions

This project utilized an agent-based model in the OSM MAST framework to determine which operational and design decisions have the largest impact on the effectiveness of a minefield. For the analysis, the term offensive denial mining (ODM) was developed in lieu of traditional categories of offensive, protective, or defensive mining to minimize sensitivity and avoid potential classification issues resulting from assessment of mining operations in specific geographies. The model simulated a friendly (blue) force deploying a minefield to disrupt the operations of a hostile (red) force. The model implemented a standard sequence of events where a blue delivery vehicle is generated and, based on the vehicle type and mine type the vehicle is employing, proceeds to either one or multiple deployment sites located approximately 50 nautical miles from the generation site. Upon deployment, the blue delivery vehicle exits the deployment zone, and red vessels in the area move to a destination point that may require transit through one of the minefields. Three classes of deployment vehicle were modeled: air, surface, and subsurface. Multiple design characteristics and operational employment decisions, such as the number of mines aboard each vessel, mine type, deployment time, and minefield geometry, were varied for each vessel. Additionally, red agent characteristics and operational decisions, such as mine detection capability, information sharing, and probability of fixing position or course change based on mine detection, were also varied within the MAST model.

ODM was defined and assessed in terms of two primary measures of effectiveness (MOE), termed delay and stop. The delay MOE was recorded as a binary variable where a score of one indicated that hostile agents adjusted course and zero indicated that no hostile agents changed course. The stop MOE was recorded as a binary variable where a score of one indicated that hostile agents abandoned their pre-defined missions and zero indicated that the hostile agents did not abandon their pre-defined missions.

NPS Hamming High Performance Computing machines were used to conduct 27,740 runs of the MAST model. Findings were grouped into two categories. Broadly, the propensity of the hostile vessel to change course or fix position upon mine detection dominated the analysis. This indicates that shaping actions which may cause an enemy to operate boldly or to distrust that a minefield is present may have a larger impact on minefield effectiveness than any characteristics of the delivery vessels or of the minefield itself. In terms of minefield deployment and configuration, the total number of mines had a larger impact than any other design or operational employment decision. Notably, the increase in the number of mines had a larger impact when the minefield size was restricted to less than 20 mines, indicating that there may be diminishing returns for larger minefield. Note that the largest minefield modeled was 120 mines and findings may change again at larger numbers. Finally, when comparing the overall effectiveness of the categories of blue vessels, airborne deployment outperformed both surface and subsurface deployment in terms of both the delay and stop MOE.

Recommendations for Further Research

This project developed an agent-based simulation of offensive denial mining (ODM) in the Modeling and Simulation Toolbox (MAST) feature of the Orchestrated Simulation through Modeling (OSM) framework. Future work is recommended to conduct more comprehensive examinations of ODM. Notably, more subjective aspects of minefield deployment are particularly interesting. As an example, the clandestine nature of subsurface deployment may not have been adequately emphasized within this study. An increased model duration or the presence of actively employed mine countermeasures operations by a hostile force may result in a preference for subsurface deployment when compared to either surface or airborne deployment, a finding that would be contrary to the results of this study. Additionally, there is substantial interest in the development and employment of sophisticated smart mines. The mines modeled in this analysis, while varied, were incapable of proposed behaviors such as communication, maneuver, and redeployment to create agile minefields. Depending on the speed of progress for materiel development of these smart mines, a follow-on study could easily implement any of these behaviors in OSM MAST to assess operational impact. Finally, future work that implements alterative use cases and scenarios would be informative. The single-year timeframe of this study necessitated a number of simplifying assumptions in terms of mine deployment size, spacing, and geometry as well as in terms of geography, bathymetry, and weather. The OSM MAST model built in this study could be adapted and customized to implement changes in any of these areas to improve the generalizability of analysis findings.

References

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Acronyms

MAST	Modeling and Simulation Toolbox
MBSE	model-based systems engineering
MOE	measure of effectiveness
ODM	offensive denial mining
OSM	Orchestrated Simulation through Modeling
USNI	United States Naval Institute