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Considerations for Cross Domain / Mission Resource Allocation and Replanning

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CONSIDERATIONS FOR CROSS DOMAIN/MISSION RESOURCE ALLOCATION AND REPLANNING

EXECUTIVE SUMMARY

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Prepared for:
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Project Summary

This research project explored emerging innovative data analytic concepts and techniques (including game theory, machine learning, and wargaming) to effectively manage and allocate warfare resources across multiple domains to address multiple missions in dynamic operations. The research team identified and characterized complex tactical situations in which multi-missions need to be prioritized and dynamic replanning is required. The team developed a conceptual approach that leverages advanced data analytics, game theoretics, wargaming, artificial intelligence (AI) and machine learning (ML) to support and enable decision-making (to best use and allocate warfare resources and forces) during those complex tactical situations. The team developed model-based systems engineering representations of the conceptual design and modeled use case scenarios involving complex tactical, operational, and strategic situations. The team envisioned and modeled an innovative wargaming decision aid to support operational level mission planners that may encounter similar complex situations requiring a dynamic cross-domain multi-mission approach at this higher level.

Keywords: *multi-mission, cross-domain, resource allocation, dynamic replanning, complexity, game theory, machine learning, wargaming, data analytics, artificial intelligence, courses of action, battle management aids, mission planning aids, system analysis*

Background

A challenge in warfare is the ability to plan and implement warfare assets (platforms, systems, forces) to best meet mission demands. This endeavor is highly complex given multiple (and often competing) missions, limited resources, the organizational command structure, doctrine/rules of engagement that must be followed, dynamic changes in the operational situation, adversaries with their own strategies, and uncertainty and incompleteness in situational awareness. This historical challenge has always accompanied warfare. The question now becomes—what insights can advanced data analytics provide to enhance the warfighter's ability to optimally plan and implement warfare assets to meet military mission demands?

Effective cross domain and multi-mission resource allocation must consider the following four challenges: (1) integrating strategic and planning level decisions with tactical decisions that are immediate and often reactive in nature, (2) optimizing warfare resources hierarchically across multiple cross domain missions, (3) optimizing warfare resources under dynamic conditions (dynamic replanning), and (4) making decisions under uncertainty.

Striving to develop military strategies, plans, and tactical courses of action (COAs) that optimize across domains and missions and can adapt to dynamic situations will be necessary to maintain superiority in future complex conflicts. This project studied three specific innovative data analytic methods that offer potential solutions to this challenge: game theory, machine learning and wargaming.

This study supports the goals of OPNAV N2/N6 Information Warfare through exploration of innovative methods and concepts that enable and enhance decision superiority in tactical warfare, mission planning, and strategic operations. The results of this study inform research and development efforts for battle management aids and mission planning systems of the future. The study provides further understanding of the problem domain and insights into the application of AI, ML, game theory, and wargaming as solution capabilities. The study applied a systems analysis

approach that included (1) discussion with the sponsor, stakeholders, and experts; (2) literature review; (3) participation in related workshops and symposia; (4) development of use case scenarios; (5) development of model-based systems engineering artifacts to represent system views, conceptual designs, and architectures; and (6) assessments of requirements, concepts, and scenarios. The research was performed by Naval Postgraduate School (NPS) faculty researchers, a systems engineering capstone team, and a systems engineering thesis student. The researchers and students had frequent communication with the research sponsor to elicit feedback and provide references and guidance.

Findings and Conclusions

This study produced findings in three general areas: (1) the characterization of complex tactical situations where cross-domain multi-mission operations are required, (2) the need for mission planning, dynamic replanning, and tactical decision-making that can address these complex situations, and (3) concepts for leveraging advanced data analytics to provide automated planning and decision aids for these applications. The study addressed the research objectives by first conducting a literature review of mission planning, tactical decision-aids, advanced analytics, game theory, and artificial intelligence. The research team, consisting of NPS research faculty and systems engineering students applied a systems analysis to characterize cross-domain multi-mission situations and develop system concepts for AI-enabled mission planning and tactical decision-aids for multi-mission resource allocation and dynamic replanning. The team conducted a needs analysis, requirements analysis, and conceptual design using model-based systems engineering tools to capture system and architectural design artifacts. The students developed names for the automated systems: the Strategic Operational Decision Aid for the automated system that could support future mission planning (Lee, 2022), and the Multi-Mission Resource Allocation system for future tactical-level automated decision support (Ghigliotti et al., 2022).

The NPS research team studied the operational need for automated planning and decision aids for cross-domain multi-mission situations that arise during military operations. The team drew upon former research that the primary investigator performed that characterized instances of complexity in military operations that result in situations that require automated decision support systems. Highly complex tactical military decision spaces can be characterized as having extremely short reaction or decision timelines, significant levels of uncertainty in situation awareness knowledge, extreme dynamics in the threat tempo in terms of heterogeneity, number, and kinematics, and information confusion with too little or too much information. These complex situations can cross military domains and involve operations in space, air, land, sea, undersea, and cyber. These complex situations can also involve concurrent multiple missions, such as anti-surface warfare, air and missile defense, undersea warfare, mine warfare, strike operations, cyber operations, operations in communication denied environments, expeditionary missions, etc. When warfare resources are needed for concurrent multiple missions, the decision space for resource allocation becomes complex. This complexity increases in cross-domain situations. Automated decision aids leveraging AI and advanced analytics is a candidate for improving (and even enabling) effective mission planning and tactical decision-making in these situations.

The study topic sponsor can use the findings of this research project as a basis for funding the research and development of advanced analytics capabilities for multi-mission cross-domain mission planning and tactical decision aids. One step is to continue studying AI and advanced data analytic methods as a means of automating mission planning and tactical decision-making. Another

step is to continue studying operational scenarios that involve concurrent multi-mission cross-domain operations. The topic sponsor can use the foundational knowledge from this study to continue to pursue these critical capabilities for the Navy.

Recommendations for Further Research

The Naval Postgraduate School study team recommends that automated methods including advanced data analytics and artificial intelligence (AI) be pursued for mission planning and tactical decision aids that can improve cross-domain multi-mission resource allocation and dynamic replanning. The team recommends further study into (1) the characterization of complex tactical situations where cross-domain multi-mission operations are required; (2) the need for mission planning, dynamic replanning, and tactical decision-making that can address these complex situations; and (3) concepts for leveraging advanced data analytics to provide automated planning and decision aids for these applications. The team recommends the following specific research initiatives as future work:

- Operational concept studies—to understand how/when complex military operational situations arise that involve cross-domain and concurrent multi-mission solutions.
- Development of modeling and simulation capabilities to support more detailed study into these complex operational situations and potential solutions.
- Continued research into advanced AI and data analytic methods
- Study into system architectures that can enable dynamic replanning to occur during tactical operations

References

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Acronyms

AI	artificial intelligence
BMA	battle management aids
COA	course of action
MBSE	model-based systems engineering
ML	machine learning
NPS	Naval Postgraduate School