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# Leveraging AI in Support of Decision Superiority  Enabling AI, a System of Systems Approach

Johnson, Bonnie W.

Monterey, California: Naval Postgraduate School

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# LEVERAGING ARTIFICIAL INTELLIGENCE IN SUPPORT OF DECISION SUPERIORITY

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Researchers:
Principal Investigator (PI): Dr. Bonnie Johnson, GSEAS, Systems Engineering
Additional Researcher(s): Dr. Doug MacKinnon, GSOIS, Information Sciences
Mr. John M. Green, GSEAS, Systems Engineering
Dr. Ying Zhao, GSOIS, Information Sciences
Mr. Tony Kendall, GSOIS, Information Sciences

Student Participation: Mr. Hugh Pollard, Systems Engineering; Mr. Jonas Brown, Systems Engineering; LT Geoffrey Grooms USN, Information Sciences; Capt Scott Wood USMC, Information Sciences; Mrs. Margie Palmieri, Systems Engineering

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Topic Sponsor Name: Mr. William Treadway, OPNAV N2/N6
Topic Sponsor Contact Information: William.a.treadway@navy.mil, 703-695-8008

**NPS NRP Executive Summary**

Leveraging Artificial Intelligence in Support of Decision Superiority

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Naval Postgraduate School, Graduate School of Engineering & Applied Sciences

# EXECUTIVE SUMMARY

**Project Summary**

The Navy has recognized the need for automated decision aids to support battle management as warfighters become overwhelmed with shorter decision cycles, greater amounts of data, and more technology systems to manage. To date, much emphasis has focused on data acquisition, data fusion, and data analytics for gaining situational awareness (SA) in the battle space. However, a new frontier and opportunity exists for using this data to develop decision options and predict the consequences of military courses of action (COA). This project studied the application of artificial intelligence (AI) methods to enable and enhance future battle management aids (BMA) for naval tactical operations. The researchers used literature review, a grounded theory research methodology, and modeling and simulation to: (1) study different architectural and AI aspects of BMA, and (2) develop and validate a theory for an engineered, complex adaptive system of systems (CASoS) solution which relies on AI and distributed intelligent agents. The study results include a validated CASoS theory and conceptual design and recommendations for AI methods including machine learning (ML), deep learning (DL), data analytics, and architectural concepts for supporting naval tactical BMAs.

**Keywords:** *artificial intelligence, AI, decision support, courses of action, COA, machine learning, ML, deep learning, DL, intelligent data analytics, unknown-unknowns, battle management aids, BMA, situational awareness, SA*

**Background**

Tactical warfare is complex (Bar-Yam 2004). The complexity, range, and speed of war are driving us to new technologies to remain competitive. Successful tactical operations require agile, adaptive, forward-thinking, fast-thinking, and effective decision-making. Advancing threat technology, the tempo of warfare, and the uniqueness of each battlespace situation—coupled with increased information that is often incomplete and sometimes egregious—are factors that cause human decision-makers to become overwhelmed. Advances in AI methods, increased amounts of data, and improvements in computational capabilities lead to a potential solution to address this complexity—a solution combining improved tactical knowledge, automated decision aids, and predictive capabilities.

AI technology has the potential to improve warfighting decisions by prioritizing threats and operational missions; determining COA options based on distributed warfare capabilities and their expected performance; and incorporating predictions of consequences into the decision loop. AI predictive analytic (PA) methods could form the basis of a near-real-time wargaming capability to support military tactical operations as well as bridge the gap between the planning and tactical domains (Johnson 2020).

There are many real-world challenges that AI technologies can address. These include self-driving cars, air traffic management, finance and market analysis, telecommunications, hospitals, medical insurance, and marketing. One aspect of the tactical domain that sets it apart is the existence of the adversary whose objective is to outthink and overtake our military. This adds another dimension to the challenge of gaining situational knowledge and making effective decisions—as the adversary is intentionally attempting to obfuscate our knowledge and counter our actions. The inherent complexities in the tactical domain include: unexpected and rapidly escalating events, deadly threats of many types, a variety of missions involving defensive and offensive operations, rules and procedures dictating COAs, inaccurate and incomplete knowledge of the situation, and COAs that produce a range of potential consequences and adversary reactions. AI technologies can support human decision-makers in facing such a complex decision space.

AI technologies have the potential to pay big dividends for naval tactical decision superiority (Johnson 2019a). AI enables BMAs for improving combat identification, identifying and assessing tactical COAs, coordinating distributed warfare resources, and incorporating predictive wargaming into tactical decisions. AI is *not* off-the-shelf, one size fits all, or self-contained. This study explored concepts for incorporating AI methods into decision aids to improve naval tactical knowledge and achieve decision superiority.

**Findings and Conclusions**

The purpose of this study was to understand how AI can be leveraged to enable naval tactical decision superiority. Specifically, the study developed conceptual designs for battle management aids that can support real-time tactical decisions by identifying COA options for distributed warfare assets. Johnson (2019b) developed a theory for an engineered CASoS solution approach to the Navy's highly complex tactical environment. The CASoS approach relies on a system of distributed intelligent agents that share and process data using AI and PA to develop effective COA options.

Several student thesis research studies supported this project. Geoff Grooms (2019) and Scott Wood (2019) both studied AI methods. Grooms studied AI methods that can support future naval tactical BMAs. Wood studied AI methods to support the search for unknown-unknowns in the battlespace. Hugh Pollard (2019) studied the use of ML methods as an application for the Close Air Support mission. Jonas Brown (2019) developed a conceptual architecture for gathering naval tactical system diagnostic information to support force readiness knowledge and self-awareness. Margie Palmieri (2019) is currently studying data architectural patterns that can support future BMAs.

Several aspects of the study contribute to an expansion of knowledge. The CASoS theory provides new knowledge in the fields of systems science, complexity science, systems of systems, and systems engineering. The thesis projects by Grooms and Wood identify several specific AI methods that have potential value to the Navy. Brown and Palmieri's studies provide a greater understanding of naval tactical architectural concepts for gathering and sharing self-awareness data and supporting future BMAs.

The primary finding of the project was the validation of the CASoS theory which demonstrated a need for a set of distributed intelligent agents that use AI methods to develop and evaluate tactical COAs. The

CASoS engineering framework enables the realization of future BMAs which will lead to naval decision superiority in the tactical realm. Additional findings of this research include the identification of specific AI methods and architectural concepts that have potential application.

**Recommendations for Further Research**

This study identifies a number of new and interesting applications and research areas. The high-level conceptualization and systems engineering approach that derived from the CASoS theory present rich areas for further research, modeling, and development.

Studying CASoS applications to complex problem domains is an immediate need with critical implications. This area of future work begins with the identification of highly complex problems, which could be addressed by a CASoS solution. Problem domain applications include: military tactical operations (including naval tactical maritime operations, army land-based tactical operations, joint and coalition theater and area operations, littoral combat, missile defense, special forces operations, space as a military domain); future complex airspace (including commercial, personal, military, and unmanned aviation); future automated land-based transportation (with future self-driving cars and associated automation in navigation and traffic control); cyberspace (as automation and networks continue to increase presenting great vulnerabilities); and global logistics operations (military, shipping, and commercial operations involving global distribution). Future work would focus on developing conceptual designs for engineered CASoS solutions to these problem domains.

A number of interesting studies can be conducted to better understand AI applications to naval warfare. Studies can include: understanding emergent behavior as designed from a top-down perspective; studying the effects of uncertainty that can result from incomplete and inaccurate data (studying how this affects knowledge discovery, PA, and decision-making); studying the expected performance capabilities of multi-level, multi-minded constituent systems under a variety of operational scenarios; studying complex problem domains based on different operational scenarios; studying temporal effects on decision-making (how decision time affects decisions and their outcomes); studying PA methods (studying their effect on decisions and decision outcomes).

Additional studies of data analytic and AI methods could support a more detailed design of CASoS intelligent agents. Many data analytics and AI methods exist and continue to be developed. A review of these methods could identify effective capabilities and applications in support of CASoS decision-making, prediction, knowledge discovery, data management, self-awareness, SA, synchronization among distributed intelligent agents, and developing confidence levels associated with knowledge and decision. Identifying these methods will support the eventual detailed design of a CASoS intelligent agent.

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## Acronyms

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| Artificial Intelligence | AI |
| Battle Management Aid | BMA |
| Complex Adaptive Systems of Systems | CASoS |
| Course of Action | COA |
| Deep Learning | DL |
| Machine Learning | ML |
| Predictive Analytics | PA |
| Situational Awareness | SA |