



Calhoun: The NPS Institutional Archive
DSpace Repository

Faculty and Researchers

Faculty and Researchers' Publications

2022

Naval Integration into Joint Data Strategies and Architectures in JADC2

Godin, Arkady A.; Green, John M.

Monterey, California: Naval Postgraduate School

<https://hdl.handle.net/10945/71937>

This publication is a work of the U.S. Government as defined in Title 17, United States Code, Section 101. Copyright protection is not available for this work in the United States.

Downloaded from NPS Archive: Calhoun



Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

<http://www.nps.edu/library>

NPS NRP Executive Summary

Naval Integration into Joint Data Strategies and Architectures in JADC2

Period of Performance: 10/24/2021 – 10/22/2022

Report Date: 10/22/2022 | Project Number: NPS-22-N279-A

Naval Postgraduate School, Information Sciences (IS)



NAVAL RESEARCH PROGRAM
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

NAVAL INTEGRATION INTO JOINT DATA STRATEGIES AND ARCHITECTURES IN JADC2

EXECUTIVE SUMMARY

Principal Investigator (PI): Mr. Arkady Godin, Information Sciences

Additional Researcher(s): Mr. Mike (John) Green, Systems Engineering

Student Participation: No students participated in this research project.

Prepared for:

Topic Sponsor Lead Organization: N2/N6 - Information Warfare

Topic Sponsor Name(s): N2/N6 Combat ID SME, Mr. William A. Treadway, OPNAV N2N6F33

Topic Sponsor Contact Information: william.a.treadway.civ@us.navy.mil (703) 695-8008

NPS NRP Executive Summary

Naval Integration into Joint Data Strategies and Architectures in JADC2

Period of Performance: 10/24/2021 – 10/22/2022

Report Date: 10/22/2022 | Project Number: NPS-22-N279-A

Naval Postgraduate School, Information Sciences (IS)

Project Summary

This effort is focused on a study to apply key aspects of a data strategy developed earlier for the Naval Operational Architecture (NOA) to Joint All-Domain Command and Control (JADC2) knowledge strategy for joint warfighting at the tactical edge and higher-level tiers (i.e., operational, strategic, and national).

A major problem that, prior to this study, was unaddressed, is a lack of a model-based definition of a “situation” which is a key term in a battlespace necessary for collaborating participants to gain shared situation awareness (SA) across Title 10 intelligence and Title 50 Services.

A method used to address significant “abstraction level” gaps between observations and concepts at any level of conceptual abstraction relies on the availability of “knowledge representation,” based on well-known principles of “Bayesian and Markov” Logic Networks and by utilizing graph model as an appropriate facility for persistent modeling and reasoning.

JADC2 imposes another challenge, which is auto-generation of contextual knowledge customized for mission-centric, collaborative, cross-organizational roles at any level of organizations’ abstractions. A net result of auto-generation would be availability of actionable knowledge leading to actionable understanding.

JADC2’s principal knowledge strategy conclusion is a need to apply causal inferencing at the very foundation of interdisciplinary areas of knowledge to drive any decision based on causal relations.

We recommend to blend “machine automated situations” with “human manual situations” as a natural progression for moving from “Asset Maneuver-to-Engagement Battlespace” domain workflow construct to organic “human-machine teaming” (HMT) decisioning domain workflow construct. Therefore, a desired effect for JADC2 domain is to insert decision-makers into the HMT workflows.

Keywords: *Naval Operational Architecture, Joint All Domain Command and Control, joint warfighting, knowledge strategy, tactical edge, tiers, operational, strategic, national, situation, knowledge representation, contextual knowledge, abstraction, logics, orchestration, human-machine teaming, maneuver, engagement, reverse engineering, workflows, decision making, cross-organizational roles.*

Background

The purpose of a study is in relation to the Chief of Naval Operations (CNO) and Joint Staff JADC2 organizations on defining operational requirements supported by scalable enabling infrastructure with great attention to the needs of the tactical edge. While Joint Staff Command and Control (JS J6) views JADC2 as a top-down enterprise, the research team argues JADC2 must be bottom-up, as operations at the tactical edge shape the rest of the enterprise. Our study views tactical edge operations as dependent on the ability of metadata catalog to capture the dynamic nature of the metadata. Our study is agreeable with the Topic Sponsor’s concern that a metadata catalog is inadequate to handle the dynamic nature of metadata for Navy and JADC2 Joint operations.

However, our study concludes that, in addition to metadata being dynamic, something more fundamental is happening at the tactical edge. One of the principal conclusions of our study is that each executable mission undergoes a multiple change of states in the world model, resulting in



NPS NRP Executive Summary

Naval Integration into Joint Data Strategies and Architectures in JADC2

Period of Performance: 10/24/2021 – 10/22/2022

Report Date: 10/22/2022 | Project Number: NPS-22-N279-A

Naval Postgraduate School, Information Sciences (IS)

different contexts. Therefore, a context-unaware metadata catalog is unable to distinguish if intersecting metadata belong to any particular context.

The results of the study are expected to greatly aid the mission accomplishment because a new type of data catalog would be capable to organize knowledge by context and, therefore, situations as they exist in their specific context. This natural separation between situations, which changes its context in time and space, will expand a knowledge of the situations to provide a greater SA to the decision makers. CDC will be capable of explaining what actually changed a context in a particular situation.

The study's methodology uses causality by positioning it at the foundational layer. We have concluded causal linkage based on "root – cause analysis" is the only possible methodology to identify situations, a prerequisite for obtaining the SA in an adaptive manner in highly-volatile operations, which is the case for JADC2 operational environments. Our original expectation of a need to detect novel situations led us to understand the criticality of knowing the context, which can be computable. Our team's hypothesis was based on deep understanding of a knowledge strategy, based on connected concepts of situations and their contexts.

This hypothesis has crystallized a need to abandon traditional metadata catalogs in favor of a "contextual data catalog." Such a prediction resulted in creation of a critical CDC criterion. This realization also forced our team to undertake a quest for commercially available CDC. It was a pure joy to find out one of the leading domestic companies in the United States just announced availability of "contextual data catalog" in October 2022. It was revealing that their major customers are start-ups, focusing on highly innovative products requiring highly adaptable and flexible data catalogs. This study helped to identify a fundamental requirement to overcome numerous JADC2 mission challenges.

Findings and Conclusions

The findings of our research study confirm, in full, our original expectations that JADC2 operational environment requires a development of a Joint Mission umbrella platform integrated with services, agencies and coalition partners. Hypothesis regarding Situation Awareness doing what it advertised turned out to be a myth. The long-term implication of our findings is the need to have a persistent monitoring of a myriad of dynamically changing situations in the chaotic battlespace. A related long-term implication is a need to persistently manage a "context" within the scope of discovered novel situations. The complexity of understanding and computing the context is heavily dependent on the heterogeneity of contributing knowledge types, including multi-media, scientific models, and such adaptive contributors as situation and workflow graph models. One of our study's principal realizations was a need to introduce flexible summarization engine capable of acting as a container and capable of imbedding the above-listed knowledge constructs to reflect the state of the world model at any time. The concept of imbedding must be based on different types of knowledge representations required to do the reasoning, utilizing heterogeneous generic and specialized logics necessary for JADC2 missions.

During the last five years, Joint Staff Futures Intel Branch was evolving "Cogent Way" (CW) project of digital modernization of JADC2 and Intel community to aggregate and reason over knowledge. Our research team at the Naval Postgraduate School (NPS) and NAVWAR plays a "Research and Assessment" role for CW. We aim to further extend semantic web knowledge by inserting valuable abstractions (e.g., causal logic to detect situations and context) and key ML/AI integrations (e.g.,



NPS NRP Executive Summary

Naval Integration into Joint Data Strategies and Architectures in JADC2

Period of Performance: 10/24/2021 – 10/22/2022

Report Date: 10/22/2022 | Project Number: NPS-22-N279-A

Naval Postgraduate School, Information Sciences (IS)

neuro-symbolic learning and reasoning). Our goal is to extend semantic web “deep-shallow” reasoning with more powerful logics due to their specialization. Our study includes technology evaluation of technologies which suggest product development of the abstractions we find valuable. For example, this includes evaluation of world.data “contextual data catalog” as a metadata catalog replacement across JADC2 tiers. The latter is a legacy approach which may not take JADC2 where we want it to go. However, we will continue evangelizing concepts of situation and context for “engagement” and “decision” adaptive workflows. In the future, we would like to see an alignment between workflow knowledge strategy and architectures with the state-of-the-art dissemination like Communication-as-a-Service (CaaS). Our research team can see multiple benefits from embracing aggregation-by-summarization principle with graph embeddings as the future frameworks for the next Generation Command and Control. The other potential benefit, which could be revolutionary on its own merit, is applying dynamic context to just-in-time adaptivity of situations and workflows. We, at the NPS and NAVWAR, would be excited to participate in semantic web knowledge representation and reasoning being extended with more powerful knowledge representation and reasoning logics. Programmable logics show a promise but require further research in determining its applicability. Our research believes in a transformative power of causality to detect novel situations and, even, utilize causality as a methodology to develop optimal courses-of-action (COAs). Finally, we witness a potential by applying multi-dimensional hierarchical cubes for modeling joint sub-organizations.

Recommendations for Further Research

The focus of our research study has been on support complex ad-hoc composable joint missions which is a major requirement of the Joint All-Domain Command and Control (JADC2) super-domain. JADC2 domain is a conglomerate of inter-operating domains using different vocabularies based on different taxonomies. Making such diverse commands, comprised of DOD services, Intel agencies and Coalition partners, to interoperate is a complex semantic undertaking.

“Cogent Way” project is a good example of what it takes to get a “knowledge and understanding” research taking off. We recommend providing a necessary funding for the “Cogent Way” data and knowledge strategy and implementation bold initiative. We understand it’s not going to be easy to get such project funded outside of utilizing “in kind” money. However, we need a baseline for advancing the knowledge strategy. Otherwise, it is hard to quantify whether the real progress in knowledge accumulation is occurring.

For further research, we recommend taking a deep look at logics: from well-understood semantic web logic to more exquisite logics like situation logic, event calculus, causal logic, action logic and even geo-spatial quantification logic. Our goal is to understand the realms of possible for such poorly understood areas in the DoD and Intel agencies as causality and its value for Situation Awareness and decision-making in obtaining knowledge of Blue Forces and COAs for the Blue and for the Red. If we start realizing a value of the context, we should strive to identify technologies that be generalized to catapult from data to knowledge above. Therefore, we should investigate existing graph-based metadata catalog technologies and identify which ones could be promoted to be “contextual knowledge” catalogs for the future. We should not be satisfied by staying at a data level and not being able to advance towards knowledge and understanding. Technologies from companies like “data.world” are good examples of thinking of innovations by inventing the abstractions.



NPS NRP Executive Summary

Naval Integration into Joint Data Strategies and Architectures in JADC2

Period of Performance: 10/24/2021 – 10/22/2022

Report Date: 10/22/2022 | Project Number: NPS-22-N279-A

Naval Postgraduate School, Information Sciences (IS)

There is a clear need to further invest into semi-automation and automation of processes. Considering partially- and fully automated workflows are advancing adaptation and allocation of resources to the execution of workflows, we must invest into the thinking on how “engagement” class of workflows collaborates with “decisioning” class of workflows. Significant attention should be brought to bear on how to we discover which workflows should be collaborating with chosen others to avoid having gaps of knowledge in knowledge acquisition. We should not discount plausible dependency between adaptive workflows and dissemination strategy and architectures. Should we invest in contextual adaptation to deliver the knowledge for decision-making with greater efficiency?

Utilization of logics is significantly unexplored area. The DoD and Intel Agencies, together with coalition partners, should bring logicians for collaboration to ensure the goals on keeping “data-information-knowledge-understanding-wisdom” (DIKUW) “in-situ” could be accomplished by choosing canonical knowledge representation. It is such representation of logical knowledge equations that would support different specialized logics with a single knowledge representation capable to transform itself to express knowledge equations required by different specialized logics.

Acronyms

C2	command and control
CaaS	communication-as-a-service
CDC	Contextual Data Catalog
CNO	Chief of Naval Operations
COA	course-of-action
DIKUW	Data-Information-Knowledge-Understanding-Wisdom
DOD	Department of Defense
HMT	human-machine teaming
JADC2	Joint All-Domain Command and Control
JS J6	Joint Staff Command and Control Branch
NOA	Naval Operational Architecture
NPS	Naval Postgraduate School
OODA	Observe-Orient-Decide-Act
SA	situation awareness

