Reduce the Warfighters' Cognitive Burden

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EXECUTIVE SUMMARY:

As the DoD and Military acquisitions shift the paradigm from antiquated software capabilities to artificial intelligence (AI) and machine learning (ML) capabilities, they need to ensure key infrastructure (big data and knowledge artifacts) also mature enough to handle the transition. Before any organizations or domains develop or adopt a strategy based on AI, ML, or any other form of intelligent system, they need to do a self -assessment that answers three key questions. How well does your organization/domain share knowledge? What is the state of your data? Do you understand the cognitive requirements? Answering and understanding these questions is the key to knowing where you are now (point A) so you can take actionable and progressive steps towards where you want to go (point B) to make your organization or domain AI-capable.

To provide the answers and/or a path to solving the questions above we execute a Mission Engineering (ME) process that analyzes the organization's or domain's state of readiness. The ME process is a detailed analysis that provides an assessment of how the people, systems, knowledge, data, and processes are aligned to the operational outcomes. ME adds a layer of operational viability to existing engineering processes with the goal of ensuring the program enhances knowledge sharing, reduces cognitive burdens, and increases semantic understanding.

Mission Engineering

This whitepaper describes the Mission Engineering process we use to create the Semantic Data Models, Cognitive Architectures and Knowledge Graphs, to provide the answer to the three questions listed above. Providing the blueprints for how an organization can enhance cognitive problem solving through machine learning or artificial intelligence. Our concept is unique since what we provide is an explicit mission engineering process that solves complex issues that occur from knowledge and understanding being fragmented. A fragmentation that increases the cognitive burden on the warfighters. We provide a solution set that develops knowledge artifacts and assess the state of the domain for implementing intelligent system or to execute efficiently in a Multi-Domain battlespace.

The ME process has roots in tactical operations and arose out of an operational need. With the abiltiy to combine data science with operational experience. The requirement for this pairing first became obvious when far too many of our after-action reviews in Bosnia, Iraq and Afghanistan focused on the lack of information and proper analysis of the information to support decision making.

> "Once while on a specific operation, with the 3rd Special Forces Group (A), we were told that the objective was supported by only light contingent of forces. However, as we approached the target area, we saw heavy equipment at the target site. During the debriefing we realized we had the information that a heavy force was possible, but because individuals responsible for informing us had too much data to analyze and not enough time it was never included in the planning."

The above example highlights the heavy cognitive burden based on the amount of data, information and intelligence places on the operators. They had to apply their own, innate knowledge and understanding to the problem without any system assistance to lessen the burden. From then on, this group started developing an ME process that would lessen the cognitive burden on the warfighter while still applying knowledge and understanding that comes with experience.

Over the years, the ME process has evolved. The output of the process is three key components: Semantic Data Model (SDM), Cognitive Architecture (CA), and Knowledge Graph (KG). The three components work together to enhance the cognitive development in the following ways:

- SDM informs the AI/ML solution on the critical structured and unstructured data that is required to access for intelligent systems. The SDM defines the semantic (machine readable) definition, provenance and relationship of the data to core operational processes to reduce the cognitive burden of a systems and warfighter.
- CAs to provide a blue print for AI/ML developers to understand the how they develop systems to a Mission Engineering standard. The CA defines the key Data, Information, Knowledge, Understanding, and Intelligence (DIKUI) knowledge resources that are required for cognitive problem solving for domain and multidomain operations.
- KGs to provide the level of detail for how the operations is executed and maps how each function, task, systems and personnel depend, create, change and access the distributed data required to make an operational decision.

Together these three deliverables will provide a proven and operationally accurate cognitive problem-solving technique, a predictive analytic capability that provides the semantics and patterns for confident decision making, a cognitive modeling tool to reduce the cognitive workload.

It is from our operational and data science experience that we developed the Process Driven Ontologies (PDOs) that are formed by combining the Semantic Data Models (SDMs), Cognitive Architecture (CA) and Knowledge Graphs (KGs) as deliverables in the mission Engineering process.

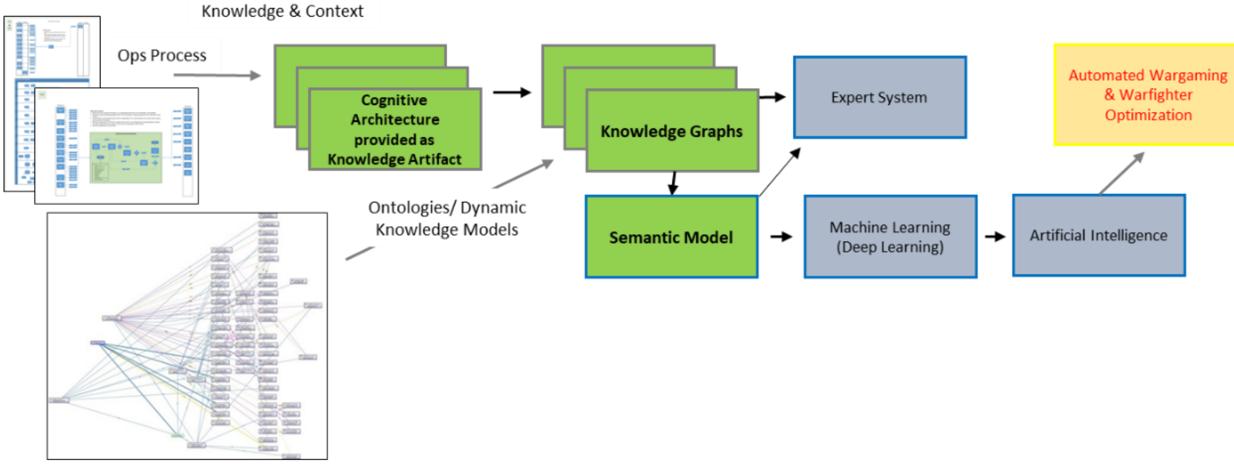

Figure 1 Mission Engineering Process

We model the organization or domain, based on doctrine, SOPs, training products and tasks lists. From this model we then define the state of data in the form of a Semantic Data Model (SDM), then extract from the model how knowledge is shared through systems and people in a Cognitive Architecture (CA), and develop a Knowledge Graph (KG) that shows how efficiently knowledge that is produced supports and is shared through the operational processes. The SDM, CA and KG are deliverables that result from the development of an operational representation of your domain in the form of a Process Driven Ontology (PDO). The PDO is a role up of the SDM, CA and KG in a universal standard while also applying operational terminology and processes as properties within the model. The Ontology is a perfect pairing of engineering practices with operational context because they describe objects in an area of interest, the attributes of those objects, and the relationships between them. They function in the same manner as how organizations typically use a database but are unique in a couple of ways.

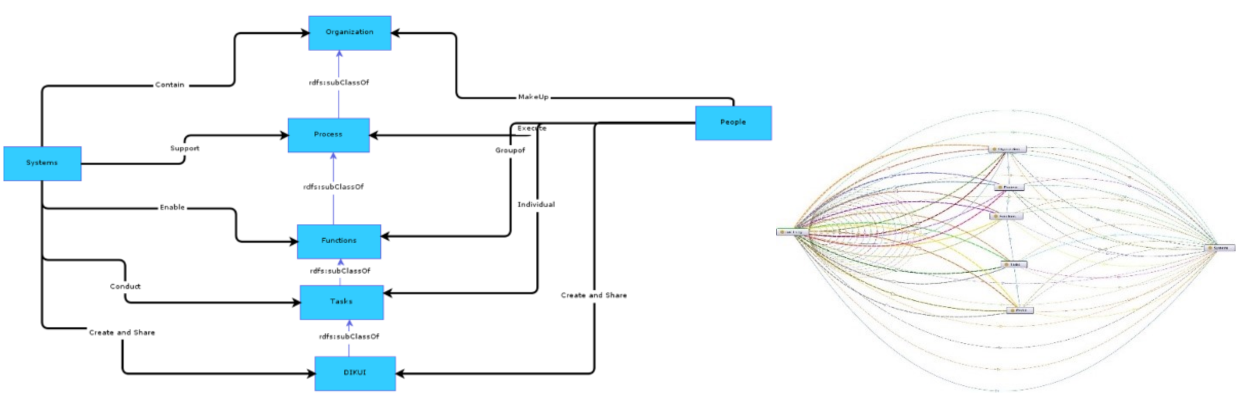

Figure 2 Example Human and Machine-readable Ontology outputs

Because they are both human and machine readable, they streamline the process of extracting knowledge from the minds of subject matter experts (SMEs) and integrating into a software application that can process the data. Since most units operate in a dynamic organization with changing priorities and missions, the data systems need to be flexible and easily extensible. The flexibility and extensibility of ontologies allows for continuous extension without having to upgrade software applications dependent on previous versions. We are not unique in the use of ontologies to solve complex data issues and create knowledge artifacts for AI. Any company/industry that is data driven and expanding into intelligent systems uses ontologies to aid the representation of the data within their domain. Companies like Google, IBM, Pfizer, Kaiser to name a few. But what makes us unique is in the development of a Process Driven Ontologies (PDOs) that define the explicit representation of an operational domain. Ontologies form the foundation of Process Group services.

How to Reduce the Cognitive Burden

Execution of the Mission Engineering process will address the state of infrastructural pieces of an organization or domain by first providing the SDM, since most of the DoD's implementation of intelligent system are slowed by "poor data" our SDM help to organize and fix the data. Second, our cognitive architectures highlight the areas in the organization where a cognitive burden exists with blue prints for how to lessen the burden. Third we develop knowledge graphs that provides a detailed representation of how critical information and data relate to the systems and process. Not only will these three deliverables help to answer the questions if the organization/domain is ready for AI but it will also deliver the knowledge artifacts to feed Artificial Intelligence, Machine Learning, Artificial Neural Networks and Robotic Process Automation (AI/ML, ANN & RPA).

Sematic Data Model-

The function of the **Semantic Data Model (SDM**) is twofold. First it is used to analyze the structure of the organization's existing data and discern its suitability to support Machine Learning (ML) and Artificial intelligence (AI) technologies. Next the SDM is used to develop the most efficient and effective manner by which the data can be leveraged by the AI process. Put another way, the SDM creates a rule set (semantics), the existing data is then organized by this rule set, then the AI consumes this data based on the rule set, a.k.a. the Semantic Data Model. Trying to develop an Intelligent system without first addressing the data, cognitive relationships and knowledge will not be successful.

The semantic models we create provide formal and explicit specifications of conceptualizations for an operational process or domain. Our SDM's play a crucial role in the representation of data in the form of knowledge to map them to the cognitive needs of the warfighter and intelligent systems. Across DoD we have been confronted with the "Garbage in Garbage out" (GIGO) when trying to leverage existing data sources. This is why we create the SDM, to extract data from a large diverse data sets, we create an ontology to formally and explicitly specify the concepts of a domain adding the semantics to describe how its data relates to each other. We can then structure the data based on operational dependencies. Especially if the large data sets are flawed, lacking in semantic and all together unorganized, the use of an ontology developed SDM brings meaning to the data, through the creation of semantic definitions and establishes better relationships to the existing data. Providing a cost-efficient solution for cleaning up large data sets by leveraging the ontology model as a semantic layer between existing databases and applications. Providing predictive analysis that can rapidly assess the data and its role in decision making.

Cognitive Architecture

The purpose of the **Cognitive Architecture (CA)** is to show how collected "Data", becomes actionable "Information" and is turned into disturbed "Knowledge" across the organization. Initially the CA explains how knowledge is shared across and outside the organization. It extends the SDM to label the knowledge as either data, information, knowledge, understanding or intelligence (DIKUI). It is through the DIKUI process that we architect how the raw data, from sensors or systems, is stored and organized. The data can be stored in a database or library. Next, the architecture maps how the data is turned into actionable information. This actionable information can be extracted in any of serval formats, including natural language chat or email messages. The CA then expands this concept to show how the combined information from internal and external sources creates knowledge. The CA enlarges the analysis to the understanding of data, information and knowledge by looking at the repetitiveness and how it is applied to a given task, function or capability. And then applies the implementation of intelligence, to any of the other forms (DIKU) that has been influenced by enemy data or from other domains. Our models, being based on operational processes, expand the semantic data models into a cognitive architecture that defines how the data, information, knowledge, understanding and intelligence from both personnel and artificial systems work together to yield intelligent behavior in diverse environments. The cognitive architecture provides a tool and technique for the assessment of reducing the cognitive burden of the warfighter.

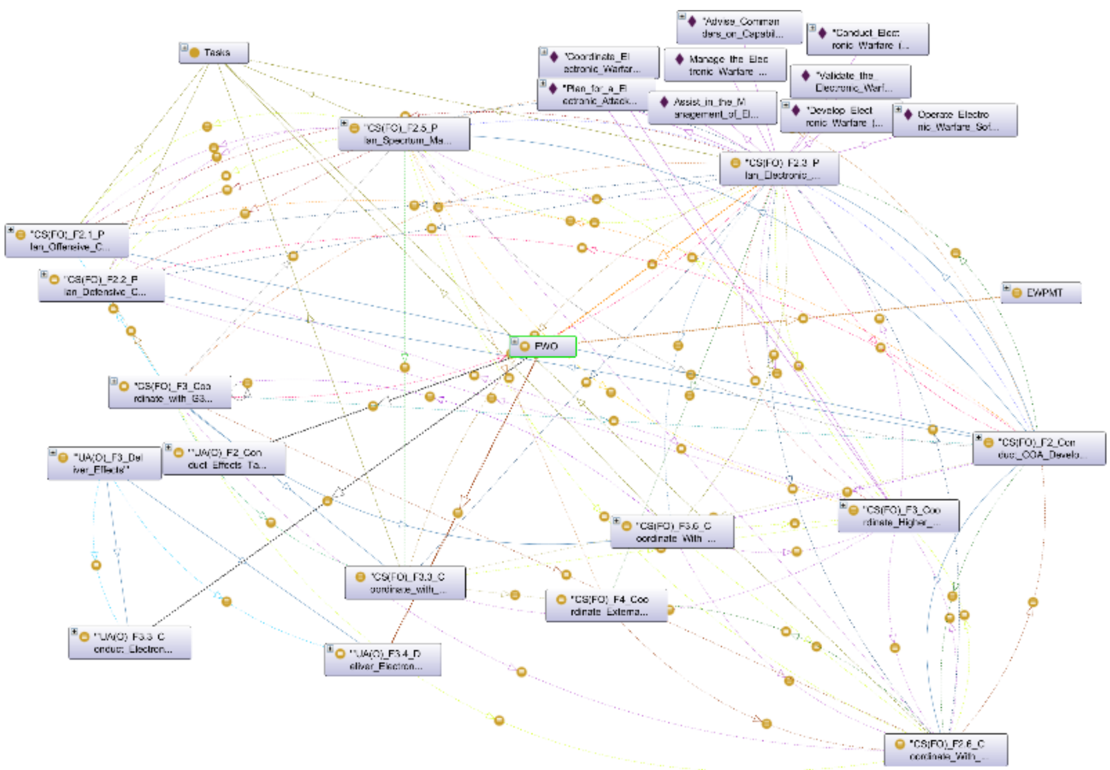

Figure 3 Cognitive Arch of an EWO task mapping

Knowledge Graph

Knowledge Graphs (KG) are a representation of the unique relations between data elements within the data set. Organizational experience, whether gained from real world events, or training exercises, which reflect external influences (the enemy, weather etc.) becomes elements within the source data, which supports the development of action information, which then adds to the organization's shareable knowledge. As the data set grows so do the number of unique relations, expanding the KGs. This becomes a cyclical process, always expanding the origination's **Knowledge Base (KB)**. The KGs are the means by how an AI Technology recognizes which data elements are important. The AI is then trained by using a KG related to a Knowledge Base or data set. Over time as the KB and KG grow, the accuracy of the AI improves, soon reflecting on more variables in a moment than a team of humans could in hours. The more data fed into an AI technology; the more patterns it will identify in the data set by means of the Knowledge Graphs. The Knowledge Graphs we create have emerged as a critical starting point for AI/ML and RPA by generating knowledge resources.

As we expand these models to describe the interrelationships of multi domain dependencies we create the knowledge graph that leverages the semantics and metadata to provide an intelligent system a knowledge base that is operationally accurate.

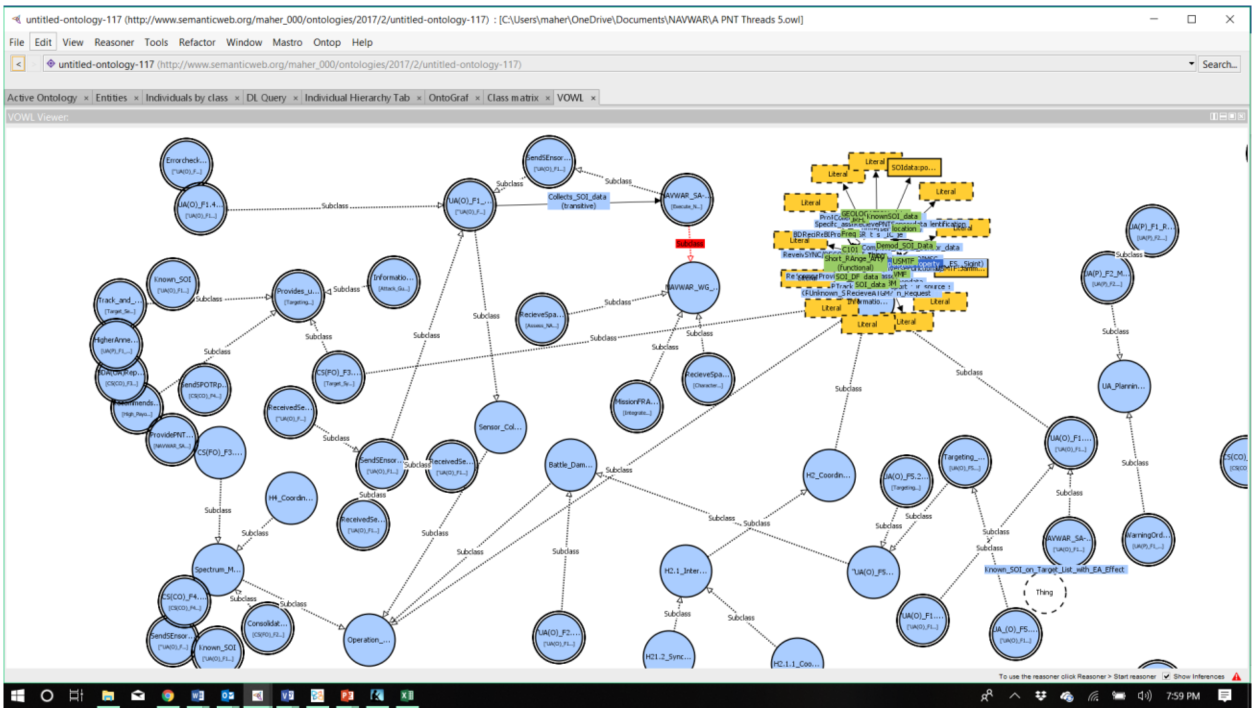

Figure 4 Knowledge Graph

Our knowledge graphs define the model "rule book" that provides the ability to learn military operations. This is critical and often the missing link in developing intelligent systems DoD.

Process Driven Ontology

It is from our operational and data science experience that we developed a unique method called **Process Driven Ontologies (PDOs)** to create the SDMs, KGs and CAs. We use ontologies rather than typical architecture tools to give us greater flexibility while still providing E2E traceability all the way from SOPs to raw data. The PDOs connect multiple perspectives in one large model while defining the SDM, KG and CAs layers, rather than creating a new architecture for each perspective. Using an ontology is far more adaptable and extensible than a relational data model; if we need to add new perspectives or relationships, we don't need to change the model. Anything relying on the previous versions is unaffected by the extensions. Our PDOs can quickly form the foundation of an intelligent system by applying knowledge of multiple functions. Teaching the system to extract the most meaning from the data quickly and, on the fly, to come up with operationally based solutions. However, the data explosion of the last two decades and the sheer volume of data available has made it almost impossible for a human to identify which data is even relevant, let alone analyze it all to develop creative solutions that will achieve the maximum effect. Attempting to accomplish this goal with training alone would be futile. Rather, we must combine the resourcefulness and ingenuity of the warfighter the advanced pattern recognition and processing power of software. However, the software must be properly trained. For the software to "learn", it needs a starting point describing how the world works so it can begin to learn and improve it's understanding to augment operations. A base built on SDMs, KGs, and CAs.

Intelligent systems will not have a basis to "learn" from without applying our mission engineering process to any intelligent systems development. The mission engineering flow that is represented in following images captures the explicate representation of a domain for CEMA Planning. This representation includes the SDM definition of the data and the model of how the data is created, modified, stored, and used in this process. It also represents the CA of how the "supporting staff" augment the planning process through the linkages of functions, tasks, system and personnel that have a role directly or indirectly of creating knowledge artifacts (DIKUI) to execute this process. An example of this would be the targeting and IPB working groups develop their own planning data and information that will correlate to information needed by the EWO to execute their internal processes.

MISSION ENGINEERING Example

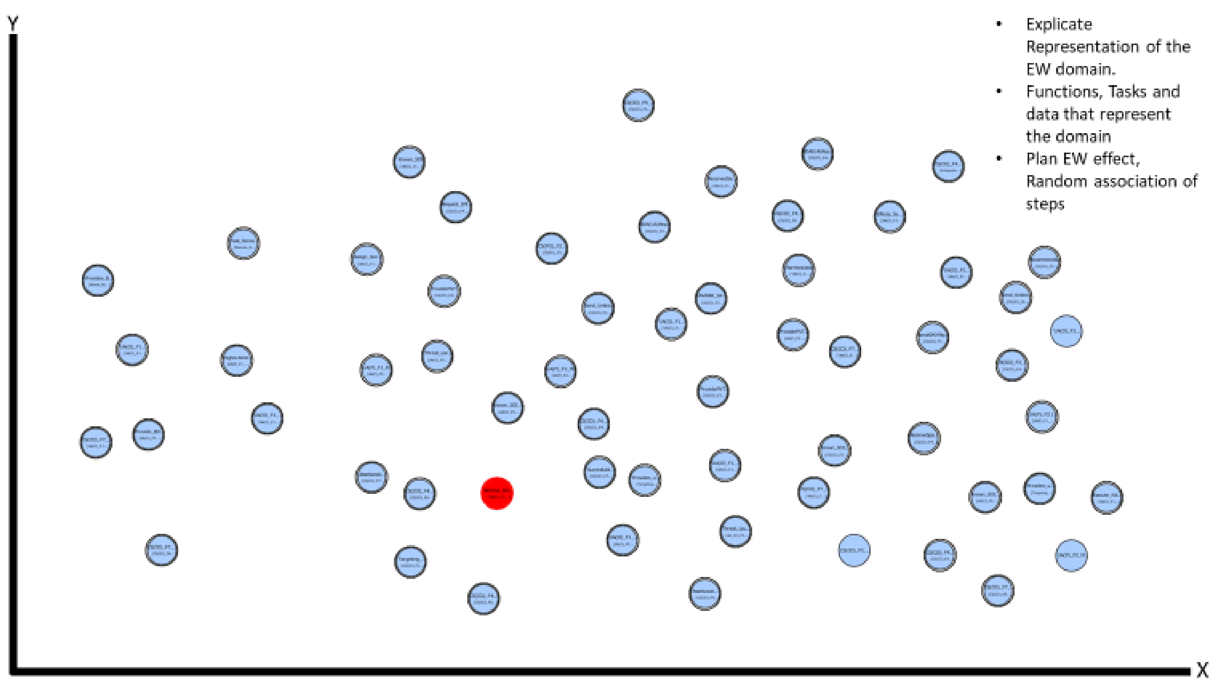

Figure 5 Representative Sematic Data Model view

Figure 5 shows a model representation of the tasks and data that is created across a staff process that does not have a defined realtionship to the EWO effort. The image represents the universe of all possible variant…an endless sea of qualitative and quantitative values without a cognitive pattern. Through analysis and software reasoning (Figure 6) our model is filtered and sampled to separate useful measurements (facts) and to form data. Data is created via our cognitive representation of the process and we start to see potential patterns that represents knowledge sharing through the inputs and outputs between systems or people in the form of Data, Information, Knowledge, Understanding or Intelligence.

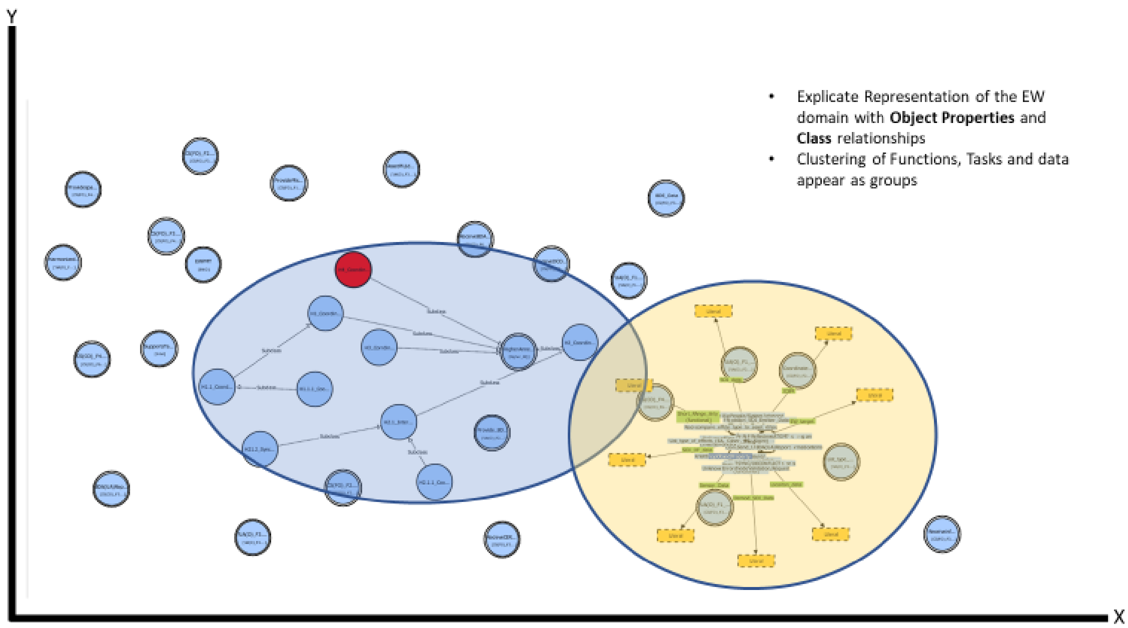

Figure 6 Cognitive Architecture applied to the data

As we inject a specific mission thread or function, in this case "Plan an EW effect". A more specific pattern evolves through providence of DIKUI that is shared to achieve the desired plan.

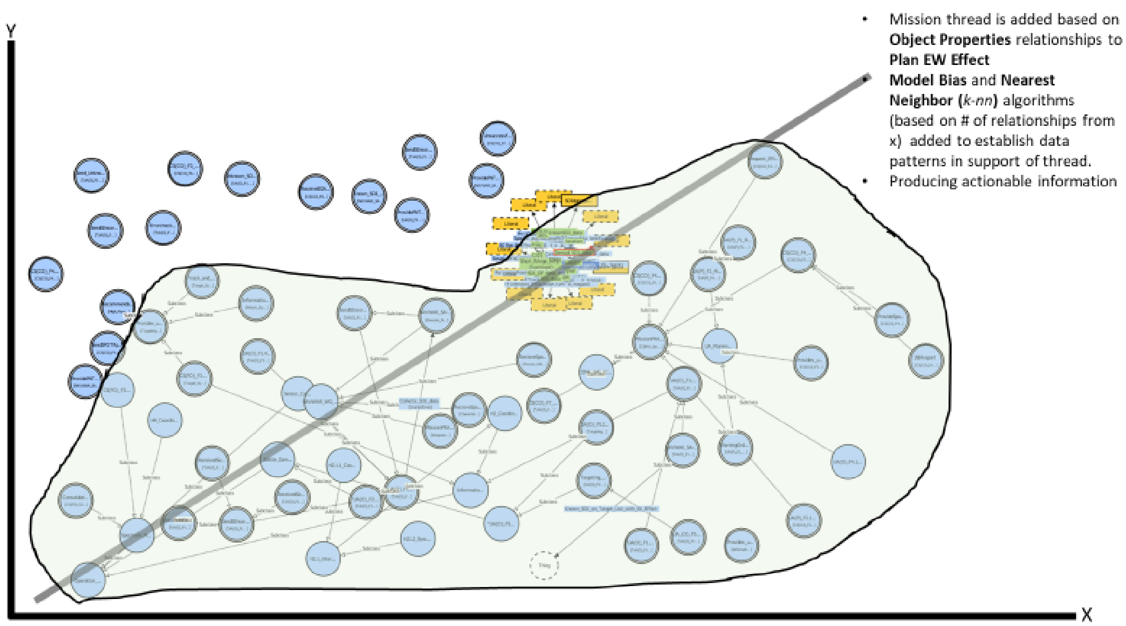

Figure 7 Knowledge Graph of a Mission thread "Plan EW Effect"

This is how we create a supervised "learning" capability for Artificial Intelligence, Machine Learning, Artificial Neural Networks and Robotic Process Automation. Providing the knowledge artifacts to implement an intelligent system. It is through this process that we can assess if an organization/domain has the infrastructural capability to reduce the cognitive burden or the warfighter.

Summary

Our modeling process allows us to model the Art of War. Where all other modeling concept model the science of warfare it is the knowledge, experience and understanding of the warfighter that is the true advantage in warfare. That is why we have spent so much time working to perfect a technique that can bring in the human aspect of war. Producing the models that combines the science and the art of war is how we can achieve better, faster and more precise decision. We address the state of infrastructural pieces by using Semantic Data Models (SDMs), Knowledge Graphs (KGs), and Cognitive Architectures (CAs) to determine what needs to be modified to enact Artificial Intelligence, Machine Learning, Artificial Neural Networks and Robotic Process Automation (AI/ML, ANN & RPA). Capturing cognitive capabilities using PDOs is a critical step for Operational Forces. The Warfighter is most effective when they can decentralize decision making through SOPs. The explosion of IT and data has caused two problems for Commanders and Staffs: degraded ability to tailor processes and procedures using current fielded systems to the data and an increased cognitive burden related to processing and finding meaning in the vast amounts of data collected. Industry is using ontologies to enhance cognitive capabilities and so can DoD. However, these capabilities require an understanding of the domains data, knowledge/understanding of a domain's objective and creation of a knowledge base comprised of facts, beliefs, basic information, and relationships that can be used to develop patterns for learning. We create knowledge artifacts based on cognitive capabilities defined by the data, processes, intelligence and dependencies to generate meaningful recommendations - a knowledge base built in PDOs that delivers a Semantic Data Model, Cognitive Architecture and Knowledge Graphs.

Our processes informs you if you are ready to move to AI by defining the state your organization. And if you are not ready then it provides the roadmap to change these areas to make you ready.