MINI-DASS: a New Missions & Means Framework Ontological Approach for ISR PED Missions . . . *the magic rabbits*

Michael A. Kolodny[a], Paul H. Deitz[b] and Tien Pham[a]
[a]U.S. Army Research Laboratory, 2800 Powder Mill Road, Adelphi, MD, USA 20783
[b]U.S. Army Materiel Systems Analysis Activity, 392 Hopkins Road, Aberdeen Proving Ground, MD, USA 21007

ABSTRACT

Today's battlefield space is extremely complex, dealing with an enemy that is neither well-defined nor well-understood. Our adversaries are "Bad actors" comprised of widely-distributed, loosely-networked groups engaging in nefarious activities to harm us. Battlespace situational understanding is needed by our decision makers; understanding of adversarial capabilities and intent is essential. Varied Intelligence, Surveillance & Reconnaissance (ISR) Processing, Exploitation & Dissemination (PED) missions are needed to accomplish this. Information sources providing mission-relevant needed information are disparate and numerous and include sensors, social networks, multimedia, internet, HUMINT, etc. Management of this multi-dimensional battlespace of informational sources is critical. This paper will present a new approach being undertaken to answer the challenge of developing battlefield understanding by optimizing the application of informational sources (means) to required PED missions as well as monitoring mission execution while coordinating, prioritizing and de-conflicting utilization of ISR assets in a multi-dimensional battlespace.

Capabilities and operational requirements are usually expressed in terms of a presumed technology solution (e.g., imagery). A metaphor of the "magic rabbits" was conceived to remove presumed technology solutions from requirements by claiming the "required" technology is obsolete. Instead, intelligent "magic rabbits" are used to provide needed information. The question then becomes: *"WHAT INFORMATION DO YOU NEED THE RABBITS TO PROVIDE YOU?"* This paper will describe a new approach called Mission-Informed Needed Information - Discoverable, Available Sensing Sources (MINI-DASS) that designs a process that builds PED-inspired missions and determines not only what the "magic rabbits" need to provide the decision maker but defines it in a manner that is machine understandable (i.e., processable by intelligent software agents).

Keywords: ISR, Mission, Means, Missions & Means Framework, Ontologies,

1. INTRODUCTION & CONTEXT

Advances in information generation technologies, the acquisition of new and smarter sensors and the proliferation of mobile devices and big data result in the production of an overwhelming amount of data which magnify the challenges to acquire and retrieve *mission-relevant information* from heterogeneous information sources. In addition, the limited quantity and capabilities of intelligence, surveillance, and reconnaissance (ISR) resources to process multiple requests for information collection creates the necessity for maximizing their utilization in order to increase the value of the information gain and the timely delivery of mission-relevant information for situational understanding for decision makers.

The problem is even more exasperated in coalition operations with the increased diversity of information sources and the *ad hoc* and highly distributed nature of such operations. Not only are ISR assets and operations more disparate, but often-conflicting coalition policies make joint ISR missions even more challenging. In today's environment of shrinking personnel and funding resources, it is essential that tools be developed that help autonomously achieve the maximization of both the utility and management of coalition ISR assets. Mission-Informed Needed Information – Discoverable, Available Sensing Sources (MINI-DASS) is a new research thrust led by the U.S. Army Research Laboratory (ARL) whose goal is to provide the tools to develop an ISR mission/task build that results in the identification of the ISR information capabilities needed for the task at hand and then to determine the ISR information generation capabilities that are available to apply against the task.

As MINI-DASS is a new research thrust, this paper will not be presenting research results but rather the long-range vision, goals, challenges and technical approach to solving the challenges and developing the tools needed. *The core essence of MINI-DASS is to provide the autonomous tools to help enhance situational understanding for the warfighter decision makers*

In the context of this paper, an ISR asset is any information source, producer or container that can deliver information to consumers (analysts, planners, decision makers). It can be a physical sensor, a human source such as social media or HUMINT from which data can be collected or an information container (e.g. database) from which information can be retrieved [1]. **Figure 1** shows a high-level externalization of the process for obtaining information for situational understanding [2]. The cycle starts with the need for situational understanding to make a military decision. A mission-driven plan, hypothesis, posing of a question or a collection call is generated. A man-machine interface is needed to translate the request so the computer can understand it. The mission-relevant data/information sources must then be engaged; they need to be discovered and then queried. To collect the necessary mission-relevant data/information, the information needs to be filtered for relevancy and then extracted. This extracted data/information may then be processed with various data analytic capabilities including fusion, correlation, aggregation, etc. Information then may be exploited, perhaps by an analyst, and disseminated to the consumers of the information to the point of need. The key elements of the representation are:

- Information query must be tied to mission/task
- Machine understanding of needed information
- Discovery and availability of *mission-relevant* information sources (ISR assets)
- Information-based hierarchy of ISR assets
    - Fusion engines
    - Information processing techniques (including PED (Processing, Exploitation & Dissemination))
    - Intelligence Products
    - Social media
    - Etc.
- Consumer externalization of situational understanding information
- Matching capability of means to mission capabilities required

This externalization illustrates the variety of candidate ISR assets for consideration to be discovered, collected, exploited, processed, analyzed, and disseminated for enhanced situation awareness and decision making. Optimizing the discovery and utility of coalition ISR assets when facing multiple requests for information to enhance situational understanding for decision makers by gathering the necessary mission-relevant information will require automated tools in support of collection planning, assessment and ISR mission execution.

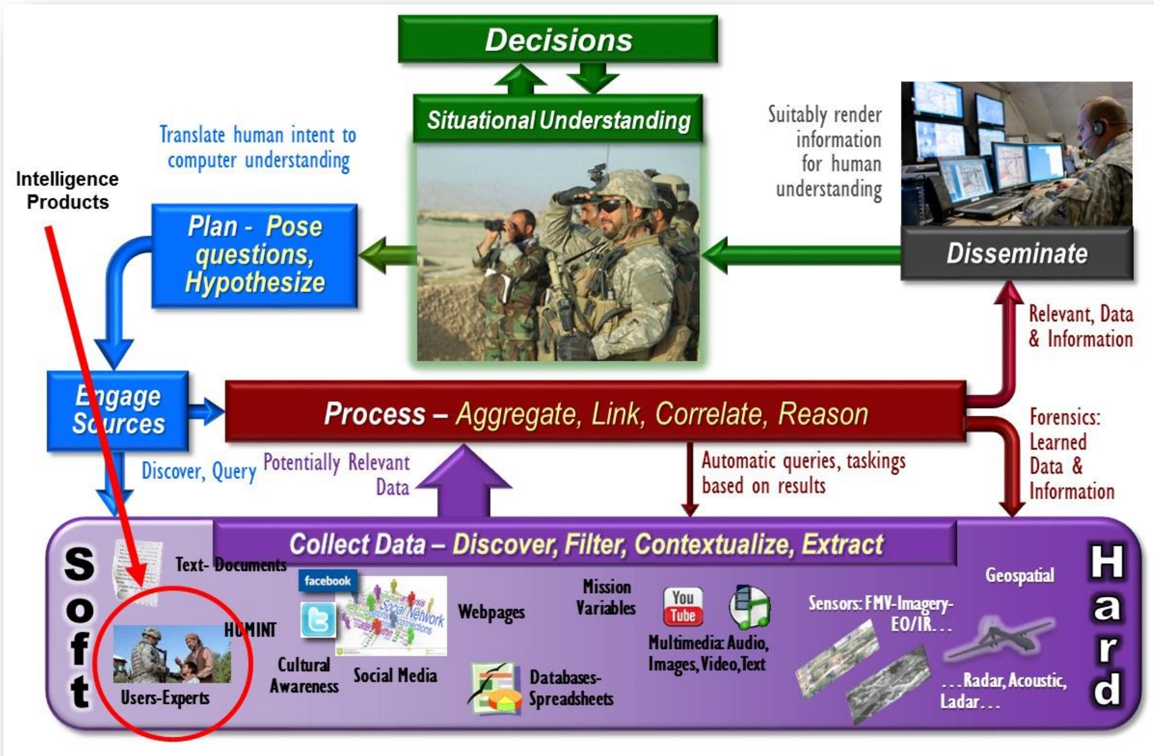

Figure 1: A representation for obtaining relevant information for situational understanding

Research by ARL in collaboration with the Network & Information Sciences International Technology Alliance (ITA) program[1] on Sensor Assignment to Mission (SAM), for the development of sensor ontologies providing rich semantic descriptions of sensor capabilities and properties is active and has demonstrated benefits for sensor integration, ISR resource tasking and information fusion [3] [4] [5]. In addition, research efforts have been directed to the development of a Missions to Means Framework (MMF) model [6]. Efforts in this area can be leveraged as a foundation and extended to meet the requirements of our research. In our efforts, in addition to developing representations of sensor properties, capabilities and availability, we are developing formal representations of different types of information produced by disparate information sources and how they help fulfill information gaps. High-level information requirements need to be decomposed into specific information requests, expressed according to concepts of these ontologies, to facilitate the matching of requirements to appropriate information sources. These models, combined with appropriate reasoning schemes, will improve current processes.

ARL and U.S. Army Materiel Systems Analysis Activity (AMSAA) are conducting related and complementary research efforts on the optimization of the utility of ISR and kinetic assets to meeting mission needs. This research effort is focused on developing extensions to the MMF for optimizing the utilization of available ISR and kinetic assets (means) to the information needed in an operation (mission). In addition, Defence Research Development Canada (DRDC) Valcartier Research Centre is collaborating with ARL and working on Coalition ISR Asset Visibility (CIAV) which is a project developing tools for the discovery of traditional ISR sensors. These research thrusts are intended to help enable enhanced situational understanding and will be leveraged by MINI-DASS.

[1] https://www.usukitacs.com/

The focus of this paper will be to describe the approach to the development of an ontology that can enable the ability to ascertain what assets are available and what capabilities they can provide to meet mission capabilities needed. The paper will focus on the MINI-DASS vision, goals, approach and challenges rather than describe technical details of the MMF that are published in other references [6],[9],[13]. For purposes of this paper, the terms *data* and *information* are used synonymously.

2. MINI-DASS CHALLENGES: DEALING WITH DATA & INFORMATION

2.1 Goal and Objectives

The MINI-DASS initiative is to develop technology that will help optimize the utility of coalition ISR assets to enhance *situational understanding* for the warfighter decision makers. One key enabler is the development technology to allow autonomous "plug and play" interoperability of disparate ISR assets [7]. Another key enabler is the development of technology that will provide the capability to discover and extract mission-relevant information from disparate ISR information sources. This is what MINI-DASS will address.

The essence of MINI-DASS is to develop an informational-focused Missions and Means Framework with an extended ontology that will enable the optimal matching of information that is available from discoverable information sources to the mission-relevant information needed to provide enhanced situational understanding to the decision maker to be able to make the best decision possible for the current task at hand.

Specific goals if MINI-DASS will be to focus on the application of an MMF to achieve a common way of describing both requested information from consumers and capabilities that can be provided by available information sources (common language) and to provide an automated tool to enhance understanding. The ISR information domain is astronomical. MINI-DASS will focus its "domain of understanding" to the environment and the threat (the "bad actors")

2.2 The "Magic Rabbits"

The key (and probably the most difficult) aspect of this effort is to determine how to utilize a model to build an ISR mission with specific ISR tasks to obtain information and have the machine understand what information is really needed by the decision maker. This is most challenging in human-to-human conversations even before addressing the challenges of translating information needs into machine understanding. In the requirements phase, operational and analyst people tend to define their informational needs in terms of a presumed (and sometimes erroneous) technology solution (e.g., "I need imagery", "I need information from X and Y sensors", "I need more bandwidth", etc.). The metaphor of the "magic rabbits" was conceived about 20 years ago out of the frustrations developed in talking to personnel about capability requirements as they (almost) always expressed them in terms of what technology should be used. In order to remove the presumed technology solution from their thinking, a metaphor was created explaining "we no longer used that technology (whatever it was); we now use very intelligent magic rabbits instead". The question always then asked was: *"WHAT INFORMATION DO YOU NEED THE MAGIC RABBITS TO PROVIDE YOU?"* This metaphor was so absurd that it was incredibly effective. When stripped of an envisioned technology and forced to really think about what was the information was needed and what was going to do with it, many requirements, operational and intelligence people did not know. Understanding what decisions makers really need to understand is difficult even in human-human conversations; obtaining machine understanding is even more challenging. While the specific mission objectives, operations and tasks most certainly inform what information is needed, we will need to create the tools that not only build an ISR mission and can determine what the "magic rabbits" need to provide the decision maker but can also define it in a manner that is machine understandable. Not only will MINI-DASS have to address the mission build, but the man-machine interfaces as well.

2.3 Challenges

Achieving the goals of MINI-DASS will require the ability to overcome numerous technical challenges as follows:

- *Mission/task building tools:* In addition to getting the machine to understand what information the magic rabbits need to provide, a mission/task building tool needs to be implemented that ties the needed information query to specific missions and tasks. Additional formal structuring to the Military Decision Making Process (MDMP) for benefit of military planners and operators is needed.

- *Determination of mission-relevant information sources (ISR assets):* Determining which potential information sources contain mission-relevant information is challenging. Potentially, there are many sources of information that *might* contain relevant information. These sources provide data in many different forms; there is hard data, soft data, structured data, unstructured data, text data, imagery, raw signature data, high-level context-rich data just to name a few. Not only is there the challenge to determine what information sources contain relevant information, but also the challenge to determine what portion of the information *within* a source is relevant. The information relevancy problem is both an intra-source and an inter-source problem.

- *Discovery of relevant information sources:* Discovery of relevant information sources may be challenging for several reasons as well. The application focus of ARL research is "at the edge" which covers both the contested urban environment and remote environments. In these areas, infrastructure is minimal or non-existent with limited bandwidth; communications and power may be very limited. In addition, the problem of ISR asset discovery is exacerbated in a coalition warfare environment. An increased diversity of the information sources exists and operations are often *ad hoc* and highly distributed in nature. Not only are ISR assets and operations more disparate, but often-conflicting coalition policies makes joint ISR missions even more challenging.

- *Development of information-based ISR domain ontology:* The defining, modeling and developing the hierarchical relationships of the ISR information source artifacts will be challenging. Some of the most relevant and prevalent information source are the most difficult to model; social media, PED (Processing, Exploitation and Dissemination) and fusion engines. Social media is generated by humans and contains soft data which is "full of opinions suggestions, interpretations, contradictions and uncertainties" [8]. It is biased, subjective, ambiguous; it and has the nature of being information of assessment rather than fact. Not only are there issues of information veracity, but also issues of echo versus direct observation with the spreading of "rumors". The PED process consists of humans (analysts) taking information from single or multiple source types and injecting context and conative reasoning to produce information at a higher level referred to as intelligence product. As with social media, modeling the human element with cognitive reasoning and the other issues noted above will be challenging. Fusion engines from an information science perspective is analogous to PED except without the human element.

- *Man-machine interfaces:* In addition to the man-machine interface needed to achieve machine understanding of mission-needed information that was discussed above, an eternalization of the machine-derived situational understanding is needed. Both of these consumer's externalizations will be challenging.

- *Matching capability of means to required mission capabilities:* This is challenging for several reasons. In this domain, there is rarely a "complete" match. More typically, *some* of the information is available; how much needs to be available for mission "success" can be quite arbitrary.

2.4 Questions of Inquiry and the Value of Information

In designing and implementing a model that performs a mission and task build, and determines what information is needed for an ISR mission, it must be determined what level of questions can be asked of the "magic rabbits" and what level of understanding does the MINI-DASS machine have and what mission-related history it has "knows" or has access to. The types of questions "allowed" by MINI-DASS must be established; can they be open questions (e.g., "What is the weather?") or must they be limited to closed questions (e.g., "Is it raining?"). In addition, the domain of allowed questions must be defined. The breadth of the ISR world can be described as astronomical. In order to be able to deal with limited resources, MINI-DASS will limit its questions to (1) the environment and (2) the threat; allowed questions will be closed.

The basic MINI-DASS challenge will be to deal with the *value* of information; not the *quality* of information. Quality of information is not only about the information itself (e.g., veracity and resolution); it's about its value as it relates to a mission need. The key elements of value of information within the MINI-DASS context are relevance, veracity, timeliness and orthogonality. Higher resolution imagery is not more valuable than lower resolution imagery for some missions. As more data is acquired from a like source, even if relevant and true, it becomes less and less valuable. If one is interested in the thermal condition at a location, getting more and more temperature readings becomes less and less valuable. Getting information from a different type of sensor or information source (orthogonality) may add significant value.

In summary, the key challenges in developing a MINI-DASS will be dealing with (1) the relevancy and value of the information and (2) the modeling of the human element of information. The initial use cases of information sources that MINI-DASS will address are social media, FMV from low-flying UAS cameras, fusion engines, PED processes and traditional low-power ground sensors.

3. IMPLEMENTATION: THE MISSIONS & MEANS FRAMEWORK MODEL

Work on what has come to be known as the Missions & Means Framework began about 2000. The MMF [9] [10] efforts resulted effectively in a framework that can serve as an analytic surrogate for the military mission build process. Although this MMF model was initially developed for kinetic force-on-force missions, it is generic in nature and will be used by MINI-DASS for ISR missions. The full MMF has been discussed elsewhere [6], so the description here will be brief.

3.1 MMF Elements

This model incorporates a multi-step process for a mission/operations/task top-down, time-backward mission build starting at national policy and going down through strategic, operational and tactical missions getting to the tactical tasks in support of mission objectives. Once the framework has been instantiated, the model will be exercised in a time-forward mode to assess mission success. The expertise of experienced operational personnel will provide the operational domain expertise to have the model determine the mission-specific information needed from the magic rabbits. The 4-level core MMF model depicted in **Figure 2** will be used for the basic MMF implementation.

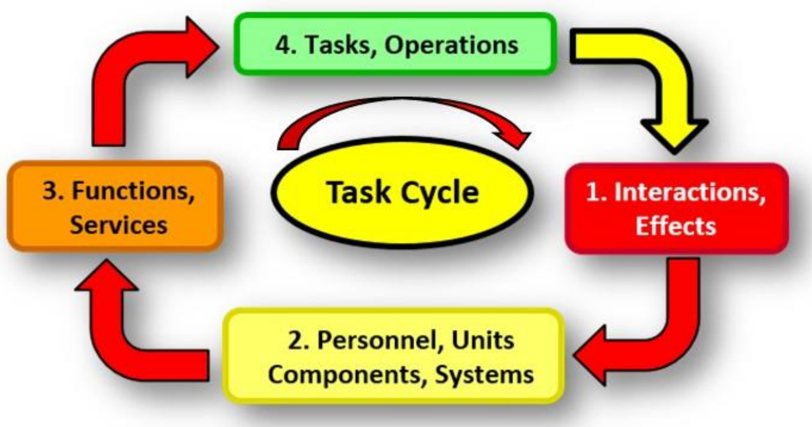

Figure 2: Time-Forward, Bottom-Up, Mission-Execution MMF Model

The levels shown represent the following:

- **Level-4 - Tasks/Operations:** Task-based, outcome-centric specification of operations that provide criteria required for the *Means* to accomplish the *Mission*. Objective: organize task outcomes and evaluate mission effectiveness. In the MINI-DASS domain, this level provides the specifications that the available sensing sources need to satisfy to provide the information the “magic rabbits” need to provide; it is the *MISSION*/task.
- **Level-3 – Functions/Capabilities:** Function-based, performance-centric specifications of “how well” the capabilities of the *Means* must perform. In the MIN-DASS domain, this represents how well the information systems and networks satisfy the information collection requirements.

- **Level-2 – Components/Forces:** Component-based, state-centric specifications of the components that provide the *Means*. In the MIN-DASS domain, these are the physical and logical networks of available information sources, systems and analytic processes and tools.
- **Level-1 - Interactions/Effects:** Interaction-based, phenomena-centric specification of effects of operations on forces. In the MIN-DASS domain, this represents the state changes of the components in an information gathering mission. This includes actions such as mission programming of assets, updating databases, reconfiguring algorithms, etc.

This model is generic and mission-independent. Applying this model to the MINI-DASS mission domain, **Level 4** represents the "acquire-the-needed-information" ISR tasks. Level-3 represents how well the capabilities of the available sensing source means satisfy the mission needs and will be the basis for determining the optimality and "goodness" of the "matches". **Level 2** represents specifications of the ISR means that are available. **Level 1** is the interactions and effects which includes mission programming and information source updating. If one views this model from a semantics perspective, the **Level 4** operations are the "verbs" (e.g., doing an ISR task), the **Level 1** interactions are the "adjectives", the **Level 2** components are the "nouns" (e.g., sensor, report) and the **Level 3** functions are the "adverbs" (e.g., how well).

The full MMF model is shown in **Figure 3** [6]. Several elements are contained in the full model in addition to the four levels described above. There is addition of the **Level 7** OWNFOR ("good guys") and OPFOR ("bad guys"). Even for a "passive" ISR mission, the model needs to have an interaction with the OPFOR for several reasons; a passive surveillance mission can have a kinetic effect in that someone that knows they being watch may take evasive action and it is the OPFOR that the ISR mission needs situational understanding of. **Level 5** is the location and time that always relevant and it applies across the four basic level described above. An additional force shown in the foreground as **Context**. The outer **Level 7** for **Context** has been left out for clarity. For an overall perspective, one can think of **Level 6**, **Context**, as initially containing all forces and equipment on all sides. From a logical process, the relevant **OWNFOR** are identified and elevated to populate **Level 2** on the left, and the same for the **OPFOR** to populated **Level 2** on the right. The rest of the levels and operators are as earlier. The grey **Context** force can be thought of as force distinct from either the **OWNFOR** or **OPFOR**, and oriented to playing some (semi-independent) role.

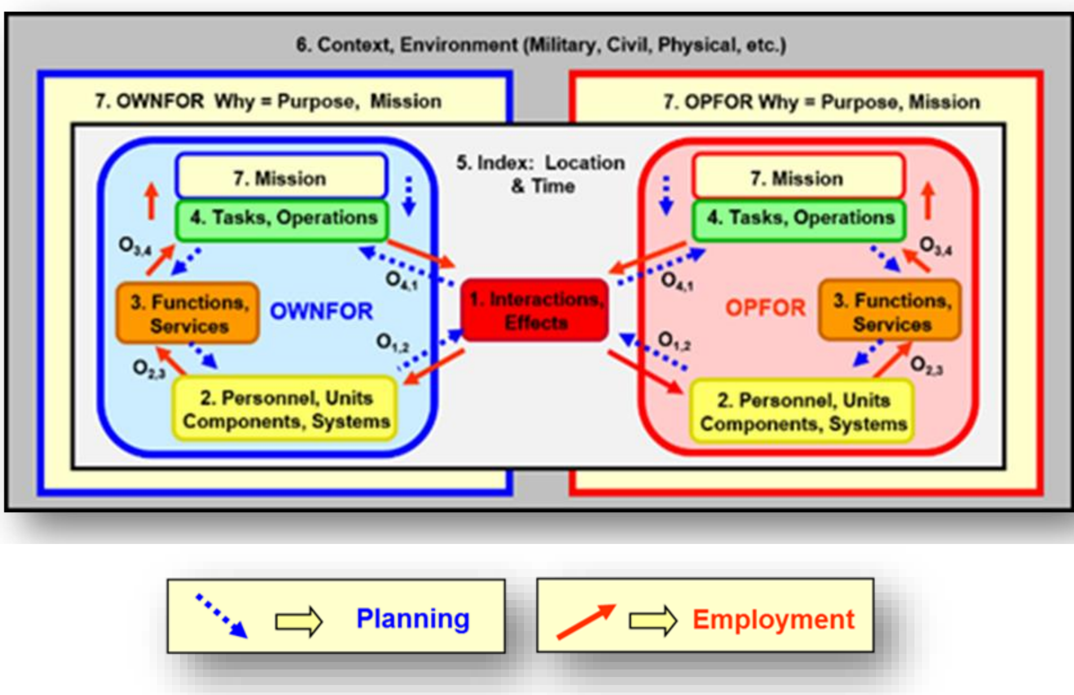

Figure 3. The full Missions & Means Framework: MMF is characterized by eleven fundamental elements: seven levels and four operators.

The $O_{1,2}$ **Operator** changes the state of the components at **Level 2**. A new capability is computed at **Level 3** and then finally compared with the capability required for the next task in the cycle at **Level 4**. If the current capability at **Level 3** meets or exceeds that called for by the next task, the process continues. One Task Cycle (i.e., one 360◦ cycle) from initiation to final capability/task comparison via the $O_{3,4}$ **Operator** might represent a single ISR task.

A key point here is that all of the executing parties are both self- and cross-linked through the same shared **Interactions** and **Effects** level shown in red. This observation is critical to both the underpinning logic of the MMF process as well as its corresponding embodiment in executable code. One of the key takeaways is that although the MMF has multiple levels connected by both explicit and implicit operators, certain levels "talk" only to other levels, and the process of level instantiation must follow a specific causal order.

4. DEVELOPING AN ONTOLOGY FOR MINI-DASS

By definition, the Missions and Means Framework provides a formal structuring to the Military Decision Making Process, for benefit of military planners and operators. The MMF model is viewed as making a first step toward formally organizing domain knowledge for mission planning and execution. This added formalism makes MMF useful for developing tools and software for military mission planning and simulation and modeling the mission space for detailed understanding of mission requirements. However, toward enabling support for software systems, additional work becomes necessary to establish machine-interpretable encodings for both MMF and its corresponding domain knowledge.

The MMF described above is generic and is applicable to ISR missions where no kinetic actions are involved. There needs to be a mission build with (**Level 4**) *Tasks* that need to be executed. These tasks require (**Level 3**) *Capabilities* that need to be provided by the (**Level 2**) *Means*. The means for ISR missions are available information sources rather than soldiers and weapons. These include means such as sensors, social media, fusion engines and PED process. The (**Level 1**) *Interactions* for ISR missions are also different than for kinetic missions in two respects: (1) the interaction with the OPFOR is passive in that it is information *about* the OPFOR is what is needed and (2) the active interactions are with the OWNFOR means in that the ISR means need to be configured (asset C2). It may be noted that a "passive" ISR mission may have a kinetic effect on the OPFOR; e.g., if someone knows they are being observed, they may take an alternative path to avoid surveillance. The utilization of MMF for ISR missions is to provide a mechanism that enhances situational understanding for decision makers.

In applying the MMF framework here, one needs to develop an ontology and models for the information sources. This can be a daunting challenge in modeling some of the most versatile information sources such as social media and the PED process. Both of these source involve humans- everyday folks in the case of social media and analysts in the case of PED that produce intelligence products and information.

While we plan to utilize a mission-independent model for the generation of MINI-DASS mission/task requirements, we need to develop the domain-specific ontology for the MINI-DASS domain means. This will involve developing an ontology for **Level 2** of the MMF model and that interacts with **Level 3** of the model. The part of the ontology which models the information sources focuses on **Level 2** while the part of the ontology that models the "goodness" of the information generated against the requirement focuses on **Level 3**. As stated above, we will initially define several cases to implement in order to evaluate the MINI-DASS direction and value. These use cases will apply for both the mission/tasks builds and the development of operational vignettes. These operational vignettes will not only need to consider what ISR assets are available but the component mission-programming capabilities as well. The vignettes are applicable to **Level 4** and **Level 1**. In the development of an ontology, one must recognize several things as follows:

- Ontologies have the advantage that we have defined in advance exactly what each class of objects (means) is and how it relates to all other objects within our domain of interest
- Ontologies are classification systems, and in the process of building the ontology we must make *a priori* decisions as to what things belong together

The approach to the development is leverage the existing model and methodology for developing the **Level 4** mission build and tasks as well as the Level 3 required capabilities. A single overarching scenario has been defined for both the kinetic and ISR missions with several initial use cases having been defined for the ISR missions. An independent **Level 2** ontology for the ISR asset information source means will be developed. In order to determine if MINI-DASS will add value and determine if we are taking the correct approach, we limit the initial information sources to UAS FMV, social media, fusion engines, PED process and traditional low power sensors such as PIR, acoustic and seismic modalities.

The MDMP/MMF will be instantiated and come together in the application of an ISR mission. We begin with a (hypothetical) Use Case in which a unit is conducting wide area security as part of a peace operations mission. Operational subject matter experts (SMEs) apply the MDMP steps to analyze the mission and then develop and analyze the means to be simulated. The Use Case may already include operations orders/plans with annexes resulting from MDMP application. Further analysis is done to parse the resulting information, identify inter-relationships and organize the resulting information and relationships using the MMF levels and operators.

5. THE ROAD AHEAD: A COALITION MMF

The longer range vision for MINI-DASS is several fold. It is the hope to expand the development of the ontology and MMF as follows:

- Include more information sources in the **Level 2** ontology than those identified for the initial use cases
- Expand the types of inquiry questions allowed by MIN-DASS
- Expand the MMF interactions to include, in addition to ISR assets for OWNFOR, but include a “COLFOR” (COALITION FORCE) for each of a number of coalition partners

Figure 4 [11] shows a representation of the basic MMF model with additional coalition partners added. This, of course, will significantly increase the complexity of the interactions portion of the MMF model. The necessity to implement multiple policies in the availability of ISR assets portion of the MMF ontology will also significantly compound the model.

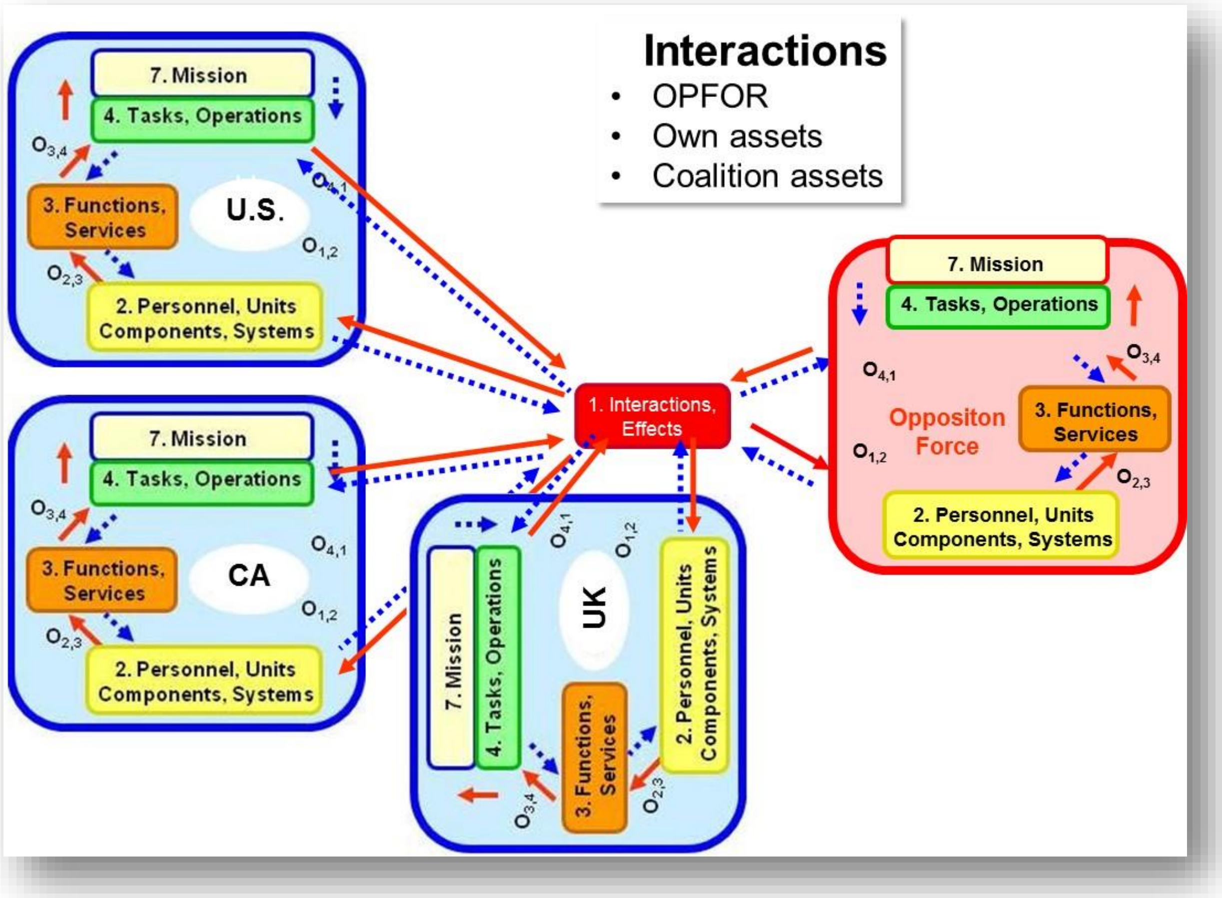

Figure 4. The full Missions & Means Framework with interactions between multiple coalition partners

6. CONCLUSION

As this project is only several months into execution, no definitive results or conclusions can be reached for this particular project goal of ISR information processing. By focusing as we are now in data/information, our attention is on the collection/processing/analysis of subjective knowledge. We are attempting something for the first time that, if successful, might have a significant impact on military operations. This is the first time that automated tools will actually do a valid mission and task build for an ISR mission in order to determine what capabilities are needed to execute successfully mission tasks. The automated tools will also determine if the means available and determine the optimal utilization of the means to be applied to the task. If successful, military operators may for the first time have automated tools that actually tie operations to mission requirements as well as have a tool for management of mission assets. Stay tuned for next year!

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