Realizing Operational Planning and Assessment in the Twenty-First-Century Air Operations Center

How a Refined Planning Construct and Semantic Technologies Can Enable Delivery of the AOC's Last Unsupported Functions (Part 2)*

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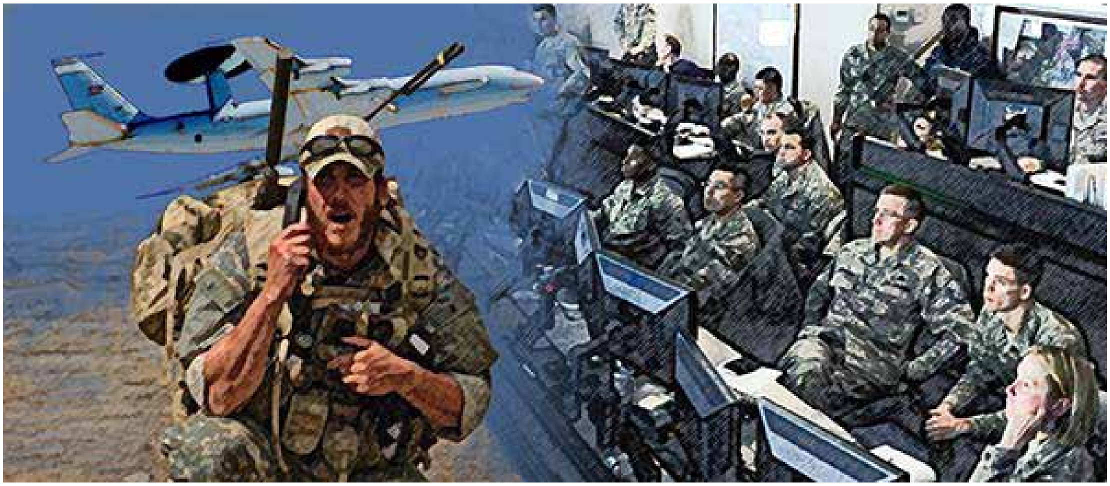

Part 1 of this article discussed the problems and failings to date of operational planning and assessment capabilities across all US government command and control (C2) domains and at all levels, including ad hoc processes, the paucity of information technology support tools, and limitations of data acquisition, correlation, analysis, and visualizations.[1] It then examined the number of these shortfalls that

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one could address through the employment of an evolutionary planning construct and methodology—Comprehensive Adaptive Planning and Execution (CAPE)—and utilization of abstract semantic operational plan models (OPM) as well as operational environment models (OEM) to realign data and enable automated reasoning and inferencing across those models.

This, the second part of the article, describes how modern semantic technologies can efficiently implement—as "services" within a service-oriented architecture—the CAPE methodology, OPMs, and OEMs as a highly practical and effective planning and assessment paradigm for the US Air Force's air operations center (AOC) of the twenty-first century. This paradigm will provide hitherto unavailable resources and capabilities to commanders, planners, assessors, and analysts for timely decision making and attainment of campaign objectives. Specifically, this part of the article addresses the solution technology involved in the generation and integration of semantic planning and environment models. It then turns to the proof-of-concept implementation undertaken in a particular operational C2 domain (i.e., the tactical assessment [TA] functions within a standard AOC). While describing the specific employment developed for the TA domain, the article shows how the solution approach could benefit and be applied in a cross-domain comprehensive approach to planning, execution, and assessment. After highlighting the solution benefits of enabling the unified and dynamic C2 that this approach can deliver, it offers some conclusions.

Solution Technology: Generating and Integrating Semantic Models

Semantic Modeling of Cross-Domain Operational Plans and the Operational Environment

Central to this proposed solution approach is the use of semantic domain models—data models characterized by the use of a formal language. The latter includes directed graphs (sets of nodes connected by edges that have a direction associated with them) in which the nodes denote concepts or entities in the world and the edges denote relationships between them. These models are precise specifications of domain concepts, which define how instance data relates to each other and to real-world categories of information. They can also include the ability to express information that enables users to interpret meaning (semantics) from the instances (i.e., the discrete data model elements). Such semantic models are fact-oriented (as opposed to object-oriented). Facts are typically expressed by binary relations between data elements, such relations usually taking the form of "triples": object <relation type> object (e.g., the Eiffel Tower <is located in> Paris). Typically, instance data explicitly includes the kinds of relationships between the various data elements, such as <is located in>. To interpret the meaning of the facts from the instances, one must know the general meaning of the relations (what does it mean to be located in?). Therefore, semantic domain models typically standardize such relation types.

Semantic models, therefore, are more than just object models or data models because they can change dynamically to accommodate growth of the domain or new knowledge based on reasoning. Furthermore, semantic models can provide a standard syntax that allows formalization of the domain—the first step toward machine-assisted understanding of that domain.

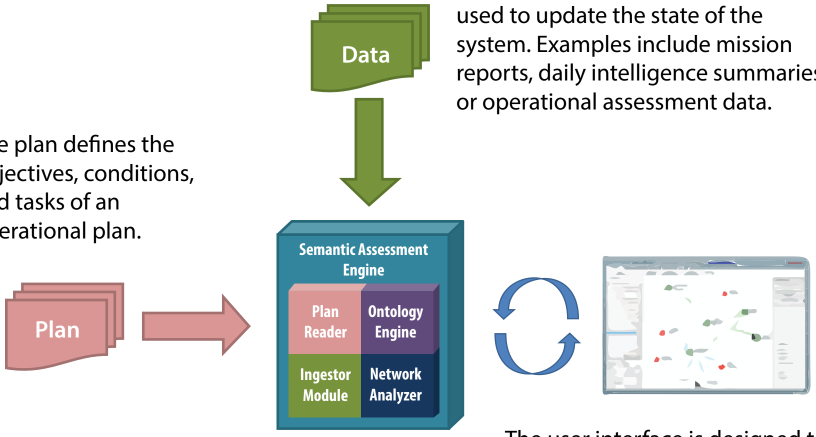
Consequently, from the perspective of cross-domain operational plans, semantic modeling enables the formalizing of knowledge in a machine-readable/processable format that spans strategy design, planning, execution, and assessment across the operational environment. Encoding this knowledge in a semantic model enables automated reasoning that supports a user-defined operational picture inclusive of the user's role and information needs across domains.

As outlined in part 1 of the article, this approach enables the development of a semantic representation of an OEM that, combined with a semantic representation of an OPM, positions the approach ideally for adaptive planning. These OEMs include taxonomies ranging from facilities, equipment, and organizations to an operational environment's "soft" factors (e.g., political, cultural, and social). These semantic OEMs have two main dimensions:

- A *stereotypical* OEM is modeled after widely used data and artifacts such as Modernized Integrated Database data, products from a joint intelligence preparation of the operational environment, and inputs from operational subject-matter experts. It is classified by type and then semantically defined using a series of semantic patterns in the form of dependencies, capabilities, and vulnerabilities. Also included for purposes of operational assessment (OA) are constructs that define possible mechanisms for the measurement and indication of the achievement (or otherwise) of plan elements. Representation of these definitions enables users to reason about and make inferences toward the state of specific OEM objects and the effect of that state on related objects throughout the operational environment.
- An *instantiated* OEM offers adversary and/or campaign specificity to the stereotypical OEM. It consists of data that represents a specific adversary, battlespace, or campaign and is populated as instances of the stereotypical constructs discussed above. One can populate the majority of the instantiated OEM from Modernized Integrated Database products; however, a small but critical part of the instantiated OEM comes from products generated by joint intelligence preparation of the operational environment. Operational-process definitions within CAPE's semantic model, as well as a user's planning domain and tools, would define the necessary tasks required for creation and maintenance of the instantiated OEM, along with available tools or services used to carry out these tasks. Once populated, the instantiated OEM is related to the OPM to complete a comprehensive semantic model.

Realization of CAPE and the Semantic Assessment Engine

An implementation of the CAPE methodology has been undertaken in the context of developing a planning and OA support system. For proof-of-concept purposes, the latter was deliberately limited to the TA function within the broader OA domain.[2] The resulting actualization of the approach outlined above—the semantic assessment engine (fig. 5)—is a system designed to implement semantic technologies to integrate and analyze data in relation to the OEM and OPM. It includes four primary components: the plan reader, ingestor module, ontology engine, and network analyzer. The engine is part of a larger "system" that makes up the entire assessment engine. Other components include the application server, database, web services, and user interface. The following sections elaborate on the designs of the modules and their contribution to the technical delivery of the semantic assessment engine.



Data, received dynamically, is used to update the state of the system. Examples include mission reports, daily intelligence summaries, or operational assessment data.

The plan defines the objectives, conditions, and tasks of an operational plan.

The user interface is designed to demonstrate the system state and capabilities. This includes all data and inferences made upon the data.

Figure 5. Semantic assessment engine

The engine begins by reading a plan based on extensible markup language from a current Air Force planning capability (e.g., Information Warfare Planning Capability or Strategic Worldwide Integration Capability) through the plan reader. It extracts plan elements and matches them with ontological structures in the OPM and OEM, categorizing them and establishing relations between the structures. The ontology undergoes an initial reasoning cycle to determine the possibility of making additional inferences to the plan. The engine checks plan entities for the presence of geographical, infrastructure, and physical dependencies and adds them to the system—for example, a hospital and power-distribution node acquiring a logical dependency due to their immediate geographic proximity (as shown in the center of fig. 2, part 1).

The ingestor module receives data from disparate sources and uses the semantic grounding mechanism—semantic patterns for actors, physical entities, concepts, and composites meshed with the relational types of capabilities, dependencies, and vulnerabilities—to identify and classify the information. The engine analyzes new messages against a set of known patterns and algorithms, and if it detects a match, passes the message data through a series of predetermined procedures for handling. Statistical data from planning or OA processes or a mission report message would fall under this category. If the data does not match any predetermined criteria, it passes to the natural language processor for data extraction—as one may find, for example, in the free-text narrative portions of a daily intelligence summary.

The natural language processor engine analyzes text by breaking down sentences or expression blocks into smaller, more manageable statements. It does so by moving statements from passive to active voice, breaking up conjunctions, and splitting up sentences based on overall complexity that includes elements such as subclauses or multiple time-manner-places (see table below).

Table. Conversion of complex to simple statement

Complex Statement	*Simple Statement*
Kennedy (subject-passive) was (aux-pass) killed (verb) in 1963.	1. Somebody (subject) killed (verb) Kennedy (object) in 1963.
Mary, John, and Joe were jumping and singing on the shore.	1. Mary was jumping. 2. Mary was singing on the shore. 3. John was jumping. 4. John was singing on the shore. 5. Joe was jumping. 6. Joe was singing on the shore.
Somebody observed local civilians traveling in the field to exchange weapons for large boxes of cigarettes.	1. Somebody observed local civilians. 2. Local civilians travel in the field. 3. Local civilians exchange weapons for large boxes of cigarettes.

Source: Attila Ondi and Anthony Stirtzinger, "Information Discovery Using VerbNet: Managing Complex Sentences," in *Proceedings of the 2010 International Conference on Artificial Intelligence, ICAI 2010, July 12–15 2010, Las Vegas, Nevada, USA*, 2 vols., ed. Hamid R. Arabnia et al. (CSREA Press, 2010), 268–76.

Extracting meaningful information from the simplified statements is an easier and more reliable task since the grammar elements more closely align with current pattern and grammar technologies.[3] General Architecture for Text Engineering breaks down sentences into their parts of speech.[4] VerbNet extracts and analyzes verbs, and WordNet—a comprehensive word database—processes all other parts of speech.[5] The extracted sentence elements then go to the semantic model to augment current definitions or provide new ones.

The ontology engine supplies the primary semantic processing for the semantic assessment engine by providing both comprehensive models of the plan and operational environment as well as the "state of the system." The Web Ontology Language (OWL)—chosen as the underlying model representation because of its good performance, expressivity, and metadata support—keeps all of this information. OWL's metadata support, which allows users to define their own properties, can extend and enhance the overall capabilities of the system, allowing for complex domain relationships. These user properties, combined with built-in OWL properties, offer a powerful platform for inferencing within a system. Examples of some of these properties include transitive and symmetric properties. A transitive property, for instance, states that for each property P, if P is a property of X and Y and if P is a property of Y and Z, then P is a property of X and Z. The preceding rule may apply to different situations; physical and logical dependencies represent one example with regard to assessment. That is, assume that site A has a critical dependency on site B and that site B has a critical dependency on site C. If site C is disabled, we can infer that sites A and B are both disabled.

Another powerful aspect of OWL is support for the Semantic Web Rule Language (SWRL), which allows users to extend properties and build complex expressions and statements for evaluating OWL ontologies.[6] For example, if entity X provides air defense cover and if Y is within X's engagement radius, then Y receives air defense cover from X. The semantic model leverages OWL and SWRL technologies to define the ontological framework. Constructs such as objects, properties, and SWRL rules are then implemented on top of these technologies to focus the domain model toward planning and assessment.

The network analyzer subsystem produces dynamic updates to the system and augments it by covering any inadequacies in the ontology models. The analyzer is implemented as a network graph that reflects the OEM and OPM as network nodes and edges. Entities in the semantic model are represented as network nodes, and the relations between the entities are graph edges (i.e., the links between them).

Further, this semantic-model-based approach readily permits the organization and presentation of data in well-formed, human-readable, and easily understandable formats. One can present hierarchical data in tree, graph, and a "line of effort" format while presenting more free-form data using concentric-viewpoint graphs. Additional visuals allow better understanding of the impact of decisions—take for example a hospital close to a high-value target. Using a standard scenario, analysts might not be cognizant of that relationship, but a means of detecting the potential link via the semantic models and a visual way of depicting the logical relationship can forewarn them of potential issues with the hospital (fig. 6).

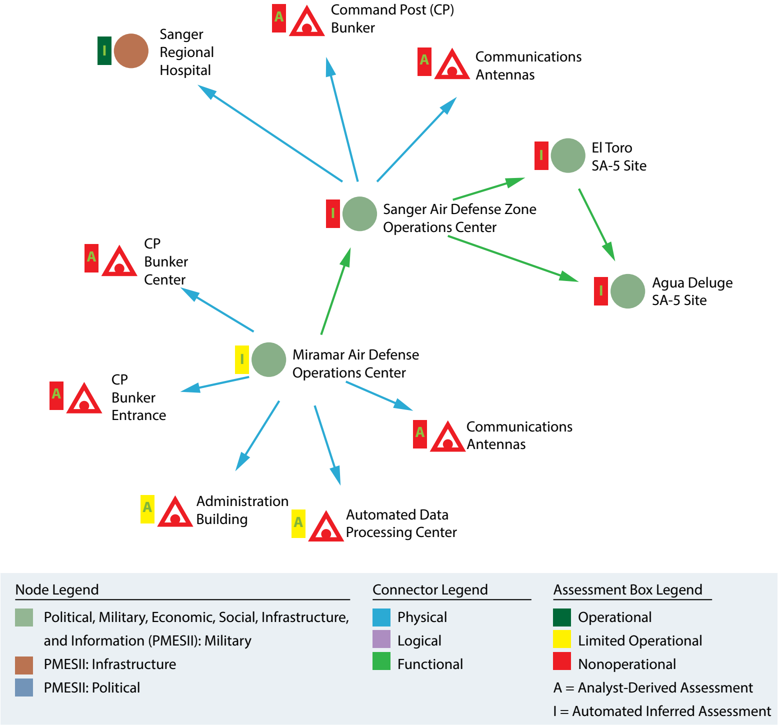


Figure 6. Visualization of OEM depicting entity states and relationships. The legend indicates the type of node and edge (link). Boxes adjacent to each operational environment node (circles) and subordinate facilities (triangles) provide related TA data. Box color indicates "system status" while the embedded "I" or "A" character indicates whether the status is "inferred" by the semantic assessment engine or formally "assessed" from within an analyst-produced battle damage assessment report.

Exemplar Solution Employment: Dynamic Tactical Assessment

Although the clear potential to employ CAPE's solution approach in cross-domain C2 at all levels of warfare was a foundational concept, the proof-of-concept implementation had to focus in on a particular operational domain. Toward that end, the exemplar case used the TA functions within a standard AOC. This section describes the specific employment developed for the TA domain and shows how the solution approach could benefit and be applied in the cross-domain comprehensive approach to the entire planning, execution, and assessment cycle.

An AOC's TA cell works directly with the operational assessment team in the strategy division:

> The purpose of TA within the AOC is to provide physical, functional and target system assessments that the [operational assessment team] will use to answer the following question, "Have our forces achieved the desired effects and ultimately, the JFACC's [joint force air component commander's] objectives?" The TA cell must be thoroughly familiar with JFACC objectives, the [operation plan], other component commanders' objectives, sortie allocation and target systems being analyzed.[7]

The TA cell uses existing targeting tools and databases, spreadsheets, e-mail, chat, and various other manual means to track mission completion and results to aggregate those results and report them to the operational assessment team. The cell will likely have responsibility for creating physical-damage and functional-assessment reports on specific target systems contained in battle damage assessment reports. Currently, the data-intensive TA processes require largely manual correlation of incoming data (e.g., mission reports, outside battle damage assessment [BDA] reports, etc.). Because of limitations in existing AOC systems, TA analysts must track mission changes and associate both mission results (from mission reports) and target statuses (from BDA reports) back to their corresponding strategy elements (e.g., tactical tasks) with no automated assistance.

Due to the overwhelming amount of incoming data, TA cells typically struggle to maintain awareness of mission results and target status changes and then report on their assigned target systems. They do very little, if any, in-depth analysis and make few recommendations beyond those based on a planned strike's not producing its direct effect on the target (i.e., a "reattack recommendation"). These limitations in current processes largely disappear with the employment of the semantic assessment engine, which will give the TA cell the following capabilities:

- Fully maintained relationships between plan and operational environment elements.
- Automated data gathering and correlation.
- Automated first-order evaluation of evidence against measures and indicators.
- Multiple ways to visualize information based on user roles.

Relationships between the Plan and Operational Environment

As discussed in part 1 and shown in figure 1, the CAPE construct is implemented in the OPM and can include all entities and relationships within a plan. For the AOC, one must remember that the "plan" isn't simply captured in a single artifact but in the dynamically evolving joint air operations plan, daily air operations directives, multiple joint integrated prioritized target lists, and daily air tasking orders, all of which provide the actual plan elements included and maintained in the OPM. One finds the planning relationships between objectives and tasks in the joint air operations plan and air operations directive, and the plan relationships between tasks and targets in the joint integrated prioritized target list. Finally, the air tasking order includes the planning relationships between targets and missions. All targets (i.e., a plan's *objects of action*) are also represented in the OEM as objects existing in the operational environment, along with any relationships between them.

Currently, because a singular AOC system does not maintain these relationships between the plan and operational environment, one must do manual reasoning across these different elements. The semantic assessment engine, however, dynamically updates models as information becomes available, and analysts can easily search the models for effects or allow the network analyzer to assist in reporting more complex indications of effects.

Relationships between elements of a plan and objects in the real world are not unique to air operations or even to military operations in general. Any structured plan (e.g., humanitarian assistance or stability operations) seeking to effect change in an environment can be represented by OPM and OEM interactions.

Data Gathering and Correlation

At present, the greatest challenge for a TA cell lies in acquiring, managing, and making sense of the large amount of data needed to assess tactical actions. New tools and databases have been developed to assist with data gathering and management for structured messages, but capability gaps remain with regard to parsing and correlating both structured and unstructured messages to the appropriate objects in the environment and associated plan elements. For example, a mission report for "mission X" arrives that depicts the results of a strike against "target Y." Because of the structured format of the report, it is relatively easy to correlate mission X and target Y to the associated tactical task through the associations maintained in the OPM and OEM. However, a daily intelligence summary—unstructured text—may also include information pertinent to the same tactical task. The semantic assessment engine's ingestor engine and its natural language processor engine can analyze this unstructured prose to extract relevant information, semantically relate it to model elements, and present it to the user. Therefore, the semantic assessment engine can automatically correlate both structured and unstructured text with little to no user interaction. These data-gathering and correlation capabilities inherent in the engine are applicable beyond the AOC environment, with many interagency organizations bogged down by the vast amounts of data that need processing and analysis. The semantic assessment engine speeds this process greatly by automating the basic correlation and processing of the information to allow users to concentrate on higher-level cognitive tasks.

Evaluation of Evidence

Well-developed operational plans include methods for evaluating those plans. *Measures of effect* and *measures of performance* are among the common terms used in the AOC. Collectively, these measures and indicators must be individually evaluated, based on incoming evidence contained in messages and other data sources.

In addition to basic correlation and parsing of messages, the semantic assessment engine assists the assessment analyst with the evaluation process. TA is primarily concerned with evaluation of the measures and indicators associated with tactical tasks, often requiring aggregation of results against a group of targets. The engine's network analyzer allows the analyst not only to see the results against individual targets and groups of targets but also to evaluate the relationships between directly affected targets and other objects in the operational environment. Again, the evaluation of evidence is not just an AOC TA cell issue. One must be able to compare new information against a standard measure in many endeavors across a myriad of operations and environment domains. Within the C2 domain, that ability remains critical to understanding whether desired effects are being produced.

Information Visualization

As explained in the section on solution technology, visualizing information is also an important aspect of this evolving capability. Despite the importance of processing information through the semantic assessment engine, it has only marginal benefit if it cannot present that information to the user. Figure 7 offers another example of a visualization developed to help commanders, planners, assessors, and analysts see the relationships between plan elements and objects in an operational environment as well as relationships between various domains and levels of a full campaign plan. This tactical-level visualization depicts a mission task with its assigned target and four facility elements within that target, along with color-coded assessment boxes (as described in the caption of fig. 6).

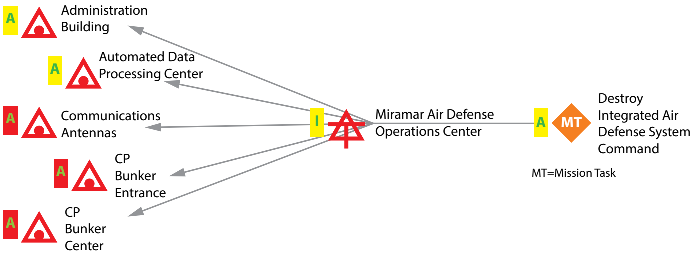


Figure 7. Visualization of both OPM and OEM elements

These types of views give all users additional ways of understanding information beyond the common tabular and tree views used on most systems today. The value of visualization lies in its utility to the user. Because of the semantic relationships maintained in an OPM and OEM, the options for visualizing the data contained therein are almost limitless. Views can be created for any level of war, instrument of power, or organization—based on the needs of each discrete user.

Solution Benefits: Enabling Unified and Dynamic Command and Control

Employment of CAPE's logical construct, semantic OPMs and OEMs, and the semantic assessment engine offers several significant benefits to the Air Force's C2 domain. The solution also has broad application across military, government, interagency, and coalition domains at all levels (strategic, operational, and tactical). Although this article has detailed only the initial proof-of-concept implementation for the AOC's

TA domain, at this writing, that implementation has been successfully extended to encompass the vast majority of the currently stated operational requirements for an AOC's higher-level operational assessment functionality. When combined with an analysis engine to reason across them, this demonstrated TA and OA functionality—along with the related semantic models that reflect the operational plan and environment—has clear potential to assist C2 planning, execution, and assessment in any domain.

This CAPE-based approach allows automatic generation of an OPM during operational design or plan development. The associated process identifies constituent objects of action, objects of effect, and causal links, enabling automatic creation of an initial plan-centric OEM if a broader, intelligence-prepared OEM does not already exist. Additionally, during later planning or subsequent operations, open-source information, intelligence reports, and/or TA and OA outputs update operational environment data within an OEM. When that data affects OEM entities and links identified as also existing in the OPM (i.e., within the plan), appropriate updates and warning flags can be generated for the user—whether analyst, assessor, planner, or commander.

The approach will also allow an operation's OPM, OEM, and their interactions to produce algorithms enabling multiple visualizations of an operation's plan, execution, assessment, and environment. For instance, they could highlight key relationships that must be managed for mission success (e.g., a planning visualization that helps cyber and air strike planners synchronize interdependent actions). Further, they can support complex analysis activities, such as an OA visualization that allows users to "drill down" through objectives, tasks, and associated measures and indicators to understand the underlying cause of poor performance against a particular objective.

Moreover, the solution approach takes full advantage of existing web services, databases, and other data sources. The approach does not require a new "system" with a unique architecture. Rather, the realized solution, using CAPE, semantic models, and the semantic assessment engine, was developed from the outset as web services within a service-oriented architecture, aimed at taking full advantage of any existing services within the current C2 domain.

At the time of submitting this article, this solution approach had been implemented as an advanced proof-of-concept demonstration for the Air Force Command and Control Integration Center under the umbrella name *Command and Control Toolbox*, that term representing the intention of developing a broad family of service-oriented-architecture-based tools for C2. In early October 2012, the center hosted a successful demonstration of the first of those intended tools—an integrated tactical assessment and operational assessment prototype capability, or Command and Control Toolbox for Assessment. Following that demonstration, the Air Force Targeting Center expressed interest in a potential Command and Control Toolbox for Targeting and Target Development. Similarly, Air Force Materiel Command expressed interest in the approach and a potential Command and Control Toolbox for Agile Logistics that could enable the dynamic integration of operations planning and associated logistics planning. Further, US Central Command has indicated that it would favor an operational transition of these concepts and their technical implementation to support combat assessment at the combatant command level.

Conclusion

This article has explained how the variability of extant planning and assessment constructs and terminology, data sources, analyst confidence, and the ability to readily understand and visualize operational schemes, plans, and evidence from the operational environment all form obstacles to effective campaign development and integration. Moreover, it has demonstrated how problems related to the access, collation, and analysis of related planning and assessment data compound those issues. It proposes that one address these current C2 deficiencies by utilizing CAPE, an evolutionary planning construct, and abstract semantic models of both operational plans and operational environments to realign and relate data as well as enable automated reasoning and inferencing across those models. With the CAPE-based solutions in play, cross-domain commanders and staffs, as well as interagency, coalition, and nongovernmental organizations, will be able to communicate operational meaning and intent in a more structured, well-understood way. Further, those solutions will open the door for technology to truly assist (through semantic reasoning) in operational design, plan development, execution, and assessment.

Given the appropriate tool support, an OPM can—in real time or as required by the user—interact with any or all available operational environment data or OEMs. For the first time, this would permit both interactive, real-time feedback during course-of-action and detailed plan development and high-fidelity strategic, operational, and higher-tactical war gaming. During operations, this approach would enable the realization of "living" plans through the constant interaction of the "living" OPM of the ever-morphing operational plan with streaming and changing outputs from the "living" OEM—constantly updated with data from both open-source and intelligence reports, execution data from live operations, and outputs of tactical-, operational-, and strategic-assessment processes.

The author believes that, just as there are few technological impediments to rapidly realizing this approach across all of the Air Force's AOCs and, indeed, the wider joint planning community, so should there be few impediments associated with interservice "operational culture." This is true primarily because the underpinning CAPE construct is a "best of breed" evolution of existing joint operational design and planning constructs, now having the innovative benefit of ontological definitions of, and syntax for, *all* elements of the construct—something sadly missing currently. Second, the use of a service-oriented-architecture-based implementation makes the solution set readily available to any and all domains yet gives each one the continued use of its existing planning systems and tools, from which it can simply import and "translate" the necessary artifacts.

Since several Air Force operations-support communities already recognize the potential of the Command and Control Toolbox, the author recommends similar expeditious consideration within the service's key operational C2 communities, particularly for Air Force forces and AOCs. This is especially prescient as the Air Force will imminently embark on the long-awaited replacement of its AOCs' current weapon system with the next-generation 10.2 weapon system, "intended to develop, field, and sustain modular net-centric [C2] applications and data management solutions for current and future C2 systems."[8] Therefore, if the AOC community, its weapon system program managers, and the Air Force Command and Control Integration Center's "capability integrators" can quickly recognize and endorse this solution approach, it is possible that the new AOC 10.2 weapon system could become the key program vehicle to "hosting" this service-oriented-architecture-based Command and Control Toolbox capability. In turn, this would allow the Air Force, after many, many years, to enable the effective delivery of both operational planning and assessment—the AOCs' last unsupported functions. Additionally, and more broadly, it would also allow the service to take the lead within the Department of Defense and joint community in making an innovative contribution to enabling unified and dynamic C2 appropriate for the twenty-first century. ✪

Notes

1. This article is an abridged, amended, and updated version of the following: Redvers Thompson, Anton DeFrancesco, and Phil Warlick, "Enhancing Command and Control (C2) Assessment through Semantic Systems" (paper presented at the 16th International Command and Control Research and Technology Symposium, Québec City, Canada, 21–23 June 2011), http://www.dodccrp.org/events/16th_iccrts_2011/papers/135.pdf.
2. Air Force Research Laboratory, Small Business Innovation Research Program, "Tactical Assessment Tools for Effects-Based Operations," contract no. FA8650-08-C-6856, completed April 2010.
3. Attila Ondi and Anthony Stirtzinger, "Information Discovery Using VerbNet: Managing Complex Sentences," in *Proceedings of the 2010 International Conference on Artificial Intelli-*

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4. General Architecture for Text Engineering, University of Sheffield, http://gate.ac.uk/.

5. Martha Palmer, "A Class-Based Verb Lexicon," Department of Linguistics, University of Colorado–Boulder, accessed 24 January 2013, http://verbs.colorado.edu/~mpalmer/projects/verbnet.html; and George A. Miller et al., "WordNet: A Lexical Database for English," Princeton University, 27 December 2012, http://wordnet.princeton.edu/.

6. Ian Horrocks et al., "SWRL: A Semantic Web Rule Language Combining OWL and RuleML," World Wide Web Consortium, 21 May 2004, http://www.w3.org/Submission/SWRL/.

7. Air Force Tactics, Techniques, and Procedures 3-3.AOC, *Operational Employment—AOC*, 1 November 2007, par. 6.4.2.2.

8. "D—Command & Control Information Svcs (C2IS) & C2 Air Operations Suite (C2AOS)," FedBizOpps.gov, 1 February 2012, https://www.fbo.gov/index?s=opportunity&mode=form&id=bda84bb9831f39b6cc393aabc80a59d3&tab=core&_cview=1.

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