Applying the DoD Architecture Framework (DoDAF) to the Commander's Predictive Environment

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Abstract

The Department of Defense (DoD) Architecture Framework (DoDAF) is a standard collection of products, diagrams, and figures typically used to describe key requirements and high-level technical factors of a system's design. Unlike traditional systems, the Commander's Predictive Environment (CPE) is a loosely coupled System of Systems (SoS) concept addressing the anticipated needs of the Air Operations Center (AOC) as it may exist in at least twenty years. This paper highlights the techniques involved in using DoDAF to properly constrain and capture CPE requirements, and discusses how integrating new Cognitive View products into the DoDAF would be useful in capturing human factors constraints that are frequently ignored during system design.[1]

Keywords: DoDAF, System of Systems, Architecture, Human Factors

1 Background

The Department of Defense (DoD) Architecture Framework (DoDAF) accomplishes for system design management what the Unified Modeling Language (UML) accomplishes for technical software and system design: notations and products are standardized into a form that can be easily described, understood (by those familiar with DoDAF terminology), and electronically captured. DoDAF is not a technical design tool, but a technical management tool promoting the complete specification of a system prior to committing to the costs associated with full system development.

DoDAF defines a collection of numbered and labeled graphical, textual, and tabular products ("views") that are developed in the course of building a given architecture description, describing characteristics pertinent to the purpose of the architecture. These views are collected into four broad categories [1, 2]:

1. All View (AV): 2 products describing the overarching system and the goals of this specific DoDAF product set, defining the scope and context of the architecture
2. Operational View (OV): multiple products containing descriptions of tasks and activities, operational elements, and information exchanges
3. System View (SV): multiple products associating systems and resources to the OV, supporting the operational activities and facilitating the exchange of information among operational nodes
4. Technical Standards View (TV): 2 views highlighting the current and anticipated standards used throughout the system, providing the technical systems implementation guidelines upon which engineering specifications are based; common building blocks are established

Only a subset of products is typically generated for a specific system, depending on the goals of the DoDAF problem set.

For the Commander's Predictive Environment (CPE) effort (described in the next section), the DoDAF products created included in the initial revision are: AV-1, AV-2, OV-1, OV-2, OV-3, OV-4, OV-5, OV-6a/b/c, SV-1, SV-3, SV-4, SV-5, SV-6, and SV-10a/b/c. Figure 1 is a collage depicting these products, intended to portray the variety of products typically produced within the DoDAF framework. Note the diversity of DoDAF products (text documents, tables, and graphics) in the image, all focused on describing some specific aspect of the CPE system. (The individual products shown in this figure are intended only as an illustration of DoDAF product diversity, and are not intended to be readable as shown in this paper.)

2 Commander's Predictive Environment (CPE)

The Commander's Predictive Environment (CPE) is an Air Force Research Laboratory (AFRL)

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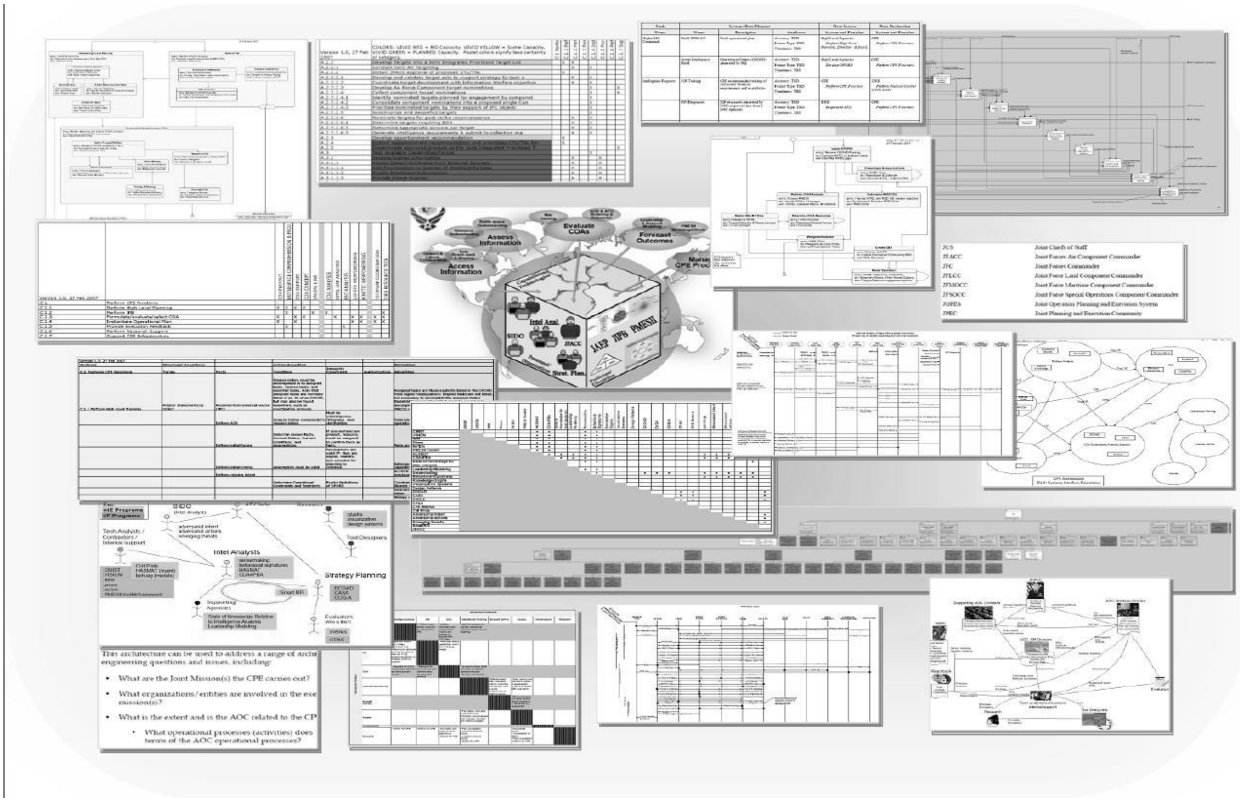

Figure 1: Collage of CPE DoDAF products

project jointly managed by the Human Effectiveness (HE) and Information (IF) directorates within AFRL [3, 4]. Each directorate oversees a collection of smaller programs contributing specific capabilities to CPE.

The overall objective of the program is to explore and develop capabilities that will enable the Joint Force Air Component Commander (JFACC) within the Air Operations Center (AOC) to anticipate and shape the battlespace, providing information that allows the JFACC and his staff to make better decisions. In addition, specific benefits to the warfighter include:

- Ability to anticipate adversary/neutrals/self strengths, capabilities, vulnerabilities, critical gaps, and possible courses of action (COAs)
- Projection of plausible "future states"
- Interactive capability to conduct "what-if" analysis and COA evaluation
- Perform operational simulations for mission training, rehearsal, and sensitivity analysis
- Visualize mission space, centers of gravity (COG), risks, uncertainty and compliance with commander's intent

CPE focuses on providing a better understanding of the past, present, and future mission space. Some tools within the CPE toolset characterize and forecast likely future events, including adversarial intent, adversarial actions/reactions, and emerging threats in Joint Operations. This information helps to generate and evaluate options, including the ability to wargame Blue, Red, and Grey COAs. Such wargaming assists in providing a training and rehearsal environment for AOC decision makers.

3 CPE DoDAF

The DoDAF is generally used to describe the architecture of an individual system and how that system relates to its external interfaces. For CPE, DoDAF is used (instead) to describe a complete System of Systems (SoS) and its capabilities, very loosely coupled, some of which do not currently exist. In this case the architecture under development is used strictly as a management tool to relate the various CPE capabilities to one another and show how these capabilities function as a cohesive tool for use by the AOC (and more specifically, by the intelligence community within the AOC).

There is already a complete DoDAF product set for the AOC focusing on current systems and operational requirements. The DoDAF for CPE begins with the list of key CPE functions and the AOC's OV-5, where the operational vision is extended several decades into the future. Substantial portions of the AOC's OV-5 are pruned away (these are AOC-specific, but not relevant to the CPE program), and a small collection of new capabilities are added to generate CPE's OV-5.

CPE is described in terms of capabilities, not specific programs. Thus, DoDAF development for CPE must overcome several distinct challenges:

1. The CPE SoS is very loosely coupled; many CPE capabilities, although they relate to the AOC, do not directly relate to one-another.

2. Some capabilities described by CPE will not be physically co-located within the AOC, and may not even be managed by AOC staff.

3. Some capabilities provide, or are based on, systems that may not currently exist; these systems could represent shortfalls.

The CPE DoDAF Architecture team[2] approached architecture design by identifying a collection of notional systems that meet anticipated operational and functional requirements. This allows us to concentrate on the specifics of CPE rather than getting bogged down in current AOC system operational concepts. Each of these notional systems can then be mapped to an existing system or collection of existing systems. Note that when no existing systems can be mapped, there are gaps in the mapping. These gaps may represent existing shortfalls, indicating areas of need for future capability development.

Another approach assisting architecture development is to consider CPE as a toolkit, rather than a comprehensive system. This technique allows us to consider CPE's loose coupling of capabilities as an asset, rather than a liability. The DoDAF products are developed to relate CPE's programs to the needs of the AOC, rather than to other programs within CPE. This also allows us to more easily overcome any perceived issues with co-location or co-management of CPE capabilities. Refer to Figure 1 to see a collage of the initial (version 1.0) CPE DoDAF products [5]. As CPE continues to evolve and focus its efforts, these products will also be revised to reflect program changes, perhaps including additional DoDAF products.

4 Integrating Human Factors

The DoDAF already includes a collection of well-defined AV, OV, SV, and TV products, and these products seem to be reasonably complete in their ability to characterize a given system's technical and interface details. However, there is no collection of views explicitly designed to capture important human factors constraints or cognitive considerations. Just like the importance of indicating data throughput requirements and system interfaces, the human factors and cognitive specifications define the important human interface needs and requirements.

The human factors community has considerable interest in identifying these components, and is especially anxious to determine a good way to formally capture them such that they can be injected into the system engineering process. There are numerous large and small research and commercial efforts to define and design processes, as well as software tools and utilities, to meet this need.

One such example is promoted within the US Navy's System Engineering, Acquisition, and Personnel Integration (SEAPRINT) program [6]. The goal of this program is to increase the attention to Human System Integration (HSI) efforts in all Navy programs by ensuring HSI considerations are applied throughout the acquisition process. SEAPRINT notes that the thorough integration of HSI into all components of the system engineering process is a chief requirement for success.

Eggleston discusses the importance of Work-Centered Support Systems (WCSS) and Work-Centered Technologies (WST) [7]. In this context, the system must be designed such that the user's work is well-represented by the system. The software user interface function as a work-aiding system, combining representational aiding with intelligent automation within a single organizing framework.

Capturing and formally representing the human-factors requirements of such designs continues to be tedious and difficult. Research performed by Knapp describes a novel approach that allows graphical user interface designs to be described by an XML-like notation [8]. This approach encourages communication between the human factors personnel generating the designs and the software technologists responsible for implementing them.

Clearly, the broad range of all human factors considerations encompasses more than the GUI specification subset thoughtfully considered by Knapp. For example, Vicente talks about five areas that must be addressed in a proper work-centered design effort: work domain analysis, control task analysis, strategy analysis, social organizational and cooperation analysis, and competencies analysis [9].

Research from Eggleston, Vicente, and numerous others will continue to guide the definition and types of products that will be useful as HSI and Cognitive Views to be added to the DoDAF. The next section is an unbiased first look at categories and types of products that may be applicable in defining such views.

[2] Key technical team members include personnel from the Science Applications International Corporation (SAIC) Dayton, OH office: Dr. Chris Hale (technical lead), Mr. Harry Heaton, Mr. Richard Loreaux, and Mr. Roger Overdorf; early work also supported by Booz Allen Hamilton (BAH): Mr. Bill Miller and Mr. Bryan Peters. Additional technical work by Mr. Joe Von Holle (Alion Science and Technology, Dayton, OH office). The author is the USAF (Government) technical lead and POC for the CPE DoDAF effort.

Table 1: Cognitive / Human Factors Views

Ontology

- Work Taxonomy / Ontology — complete dictionary of terminology and vocabulary needed to represent the work effort
- Training Requirements and Certifications — table of minimal (threshold) and desired (objective) training and certifications

Constraints

- Ergonomics — table of ergonomic issues under consideration, including environmental and physical constraints
- Time Constraints — notes indicating special timing requirements for certain work or tasks
- Cultural & Regional Expectations — cultural/regional understandings that might lead to miscommunication or task deficiencies, or even improve task performance

Usage

- System Usage / Process Patterns — description of established or anticipated patterns of usage, to include instructions or guidance
- Decision Making — paradigms used to make decisions about information provided to or by systems
- HCI / HSI — Human-Computer Integration / Human-System Integration
- Data Relevance / MLS — identification of correct amount or classification of data to be presented to a selected user or user group

Cognition

- Workload / Memory Load — appropriate measures of cognitive and memory load
- User Stress — appropriate measure of user stress level for certain tasks
- Attention & Vigilance — amount of attention or vigilance required for successful task performance

Other

- Work & Shift Transition — methods and measures for transitioning work between shifts or teams
- Team Coordination and Collaboration — mechanisms describing how collaboration and team interaction takes place
- Test & Evaluation Metrics — techniques used to measure task success and improvement (includes verification and validation)

5 New HSI & Cognitive Views

One mechanism for integrating human factors into the architecture is to generate cognitive and human factors products that are actionable parts of the design. In order to be effective, a collection of cognitive (or human factor related) views must be created and integrated into the DoDAF. Table 1 highlights a conceptual breakout of such views, with views collected into five distinct groups. (The contents of this list and its subsequent grouping is strictly the author's first thoughts on such material.) The idea is to capture human factors considerations in a series of well-specified products, in a form similar to existing DoDAF products, providing managers and lead engineers the information required to understand and anticipate significant human factors issues impacting the system being designed. These views correspond to both human factors (including HSI) and cognitive requirements.

The first group, Ontology, contains a view that captures the work ontology, as well as a product containing a complete list of training and certification requirements. Training might include skills, abilities, and knowledge in addition to certifications or academic degrees. Collectively, these views set the basis for the the top-level human factors views by putting the reader in the right frame of mind to understand the work effort.

The Constraints category contains a collection of views that bound the work requirements. An ergonomics view depicts the system from a human-centric physical and environmental perspective. Time constraints are noted for specific tasks or work, to show where parts of the system or process must meet timing requirements. A Cultural and Regional Expectations view is intended to reduce instances where misunderstandings due to cultures or subcultures might interfere with successful completion of the work tasks; this is done by defining ambiguous terms and highlighting process methods and expected results. Certain cultural or regional understandings might also improve task performance, and could be taught to newcomers.

Usage is a collection of views about how the system and system's data is perceived by the user. The System Usage and Process Patterns view includes instructions and guidance on information flow and system usage process. This view also identifies and defines work patterns that may exist by relating work to similar types of work in other parts of the system (or in other environments). Decision Making concentrates on the movement of system information when it is outside of the system, or, more accurately, when the human is the operational part of the system. This view is related to the HCI / HSI view, which concentrates on "momentum-conserving" methods for transferring information between the user and the system. The Data Relevance view is closely related, identifying the portions of the data useful for each user or user group.

Workload / Memory Load is part of the Cognition collection. This includes the identification of workload requirements and expectations within the system and process. User Stress identifies segments where the user stress level is expected to be disproportionately high or low with respect to other tasks. This is related to the Attention and Vigilance view, showing where the user must be particularly attentive for successful task completion.

The Other category is primarily about user and team interaction and user-system-user relationships. Work and Shift Transition, for example, describes how to move a user's mental model of the task to another user (through the system) as the shift terminates or users are exchanged (consider tasks such as air traffic control, for example). Similarly, the Team Coordination and Collaboration view is a product describing how teams of users can use the system to interact with one-another and with other teams. Finally, the Test & Evaluation Metrics is a structured mechanism for defining and measuring continuous improvement.

The key to the successful development of these views rests in their defined completeness, availability of data, and degree of integration into the rest of the DoDAF products. Several of the proposed views from the table certainly rely on a coupling to other components of the DoDAF. A roadmap for developing these views, and how they integrate into DoDAF, will help ensure their utility in an overarching program architecture.

Note that this list of views and its division into the five categories described above is an initial revision considered to be a very early work in progress, and will be an input as a basis to CPE's Cognitive View products. The Dayton (Ohio) SAIC office is under contract with the USAF to pursue the definition of "Cognitive Views" within the CPE program. This work, technically directed in part by the author, is expected to produce additional views that will enhance the existing DoDAF product set. Of course, we intend to fully leverage any existing efforts as our understanding of HSI and DoDAF integration evolves; we are already receiving leads for work that may contribute to this research. By the end of our own work, a representative sample of relevant products will be generated to reflect the salient cognitive aspects of the CPE functional and operational requirements.

6 Conclusions

Development of an appropriate subset of the DoDAF products is an excellent way to ensure that all system functions and interface requirements are fully and carefully considered. The DoDAF is mainly a management architecture in this respect, since it does not generally define low-level technical implementation details. Nonetheless, the DoDAF products are valuable in that they provide system designers, users, and managers with common vocabulary for describing a system. One everyone understands what content to expect in each view, and relevant products can be addressed, requested, and referenced merely by product name (i.e., "I'd like to see your OV-5 for this system").

CPE presents a special challenge, since it is distributed loosely coupled collection of tools (a System of Systems, only of sorts) and does not fully define an entire system from front to back. In addition, the CPE program concentrates on capabilities that are desired within the next several decades, which forces a reasonable architectural design to use a concept of notional systems rather than listing systems of record.

Finally, the Human Effectiveness Directorate within AFRL is especially interested in formally describing certain human factors and cognitive components. Even though limited tools already exist to assist with the identification and integration of human factors within a systems engineering process, the products these tools produce do not meet any common standard. Since these products do not exist within DoDAF, it seems reasonable to capture cognitive and human factors issues within the US Government-mandated architectural framework by generating a collection of general-purpose Cognitive Views that can be fully integrated within DoDAF. The CPE program, currently scheduled to complete in 2011, is an ideal venue for demonstrating examples of such products.

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