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THE FUTURE OF C2

Applying Multi-Agency Executable Architectures to Analyze a Coastal Security Operation

#297

Topics
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Abstract

U.S. Federal agencies face the challenge of conducting a dynamic analysis of their architectures to determine the performance and effectiveness of the business processes and the supporting Information Technology (IT) systems. Most architectures are static representations and lack the capability to support the dynamic analysis required to generate the performance and effectiveness metrics. There is an added challenge for organizations that must interoperate with other Federal agencies. Failing to integrate with other agency architectures may create critical interoperability problems resulting in mission failure. The challenge is not only to ensure satisfactory interoperability, but also to determine that the mission will in fact be accomplished and that critical gaps do not exist among the architectures. This paper discusses a case study that addressed these challenges by examining an operation where architectures from multiple agencies, using different frameworks, were integrated to accomplish a coastal security mission. The paper describes the technical approach involving two phases. The Static Phase developed a Multi-agency Operations-Centric Architecture Activity Model consisting of the mission, supporting operations, and mission-essential tasks. The Dynamic Phase took this activity model and imported it into a set of simulation tools. The paper also identifies insights about applying multi-agency architectures.

Introduction

The Clinger-Cohen Act, and Office of Management and Budget Federal Enterprise Architecture (OMB-FEA) guidelines dictate the development and use of Enterprise Architectures in the Capital Planning and Investment Control (CPIC) process for acquiring information systems. [1][2] Enterprise Architectures represent perhaps the most complete set of information on the structure of an agency enterprise; however they are static point representations. Emerging capabilities for mission and business performance simulations enable the coupling of static architecture elements to a dynamic simulation environment – the executable architecture.

Under current guidelines, Federal agencies must develop and document information technology (IT) architectures by using a framework to guide the descriptions of these architectures. A framework provides the rules, guidance, and basis for developing and presenting architecture descriptions in a uniform and consistent manner and is intended to ensure that the architecture descriptions can be understood, compared and related across organizational boundaries. To accomplish this, a framework defines numerous products to capture specific architectural views. Architecture products are those graphical, textual, and tabular items that are developed in the course of building a given architecture description that describe characteristics pertinent to the architecture's purpose. A framework by definition is very flexible, which is valuable in allowing each organization to document architectures in a way that is best-suited for the individual organization. However, because of this flexibility, there are not only multiple frameworks that meet the requirements, but also multiple tools to implement each framework.

A majority of the framework products currently being produced provide "static" representations of information for their various views. While these static products capture enormous amounts of information about the Operational Architecture (OA) components (business processes, activities, information flow, and organizational structure), and the System Architecture (SA) components, they fail to provide a good vehicle for conducting detailed dynamic "behavior" analysis of how the components are supposed to interact with each other.

This paper discusses the methodology and challenges in applying architectures of multiple agencies to support a common mission. The methodology uses executable architectures to conduct a dynamic analysis of operations performed by the agencies assigned to the mission. The approach to the analysis was in the form of a case study that involved a homeland security mission.

Objective

The objective of this case study is to examine the technical challenges and issues associated with interoperability and information sharing when multiple agencies, represented by different architectures built with different architecture frameworks, must function together to accomplish a mission. To address issues associated with multi-agency operations, we use a case study involving activities drawn from the Universal Task Lists of participating agencies executing a large coastal security operation. These mission-critical operational activities provide content for the Enterprise Architectures of participating agencies.

Note: Due to sensitivities in the scenario, specific details of the case study will not be discussed here.

Technical Approach

The technical approach divided the case study into two main phases, a Static Phase and a Dynamic Phase. The Static Phase addressed the assembly of the multi-agency architecture products needed to describe the organizations and information flows for a selected scenario. The Dynamic Phase addressed the approach to examine the performance and effectiveness of the multi-agency architecture in the operational environment described by the scenario.

The technical approach applied many of the insights and lessons learned from two previous MITRE research projects, the Multi-agency Enterprise Architecture Planning Framework MITRE Sponsored Research (MSR) and the Executable Architecture Methodology for Analysis (EAMA) Mission Oriented Investigation and Experimentation (MOIE).

The MSR provided the multi-agency framework for much of the Static Phase of the case study. This previous research helped define the concept of a Multi-Agency Operations-Centric Architecture, an architecture that is focused on conducting operations associated with a specific mission or an Operations Plan (OPLAN). [3] This approach is in contrast to a Unit-Centric Architecture that focuses on an organization's structure and how it accomplishes numerous activities related to multiple missions. The concept of the Multi-Agency Operations-Centric Architecture and its relation with individual agency architectures is illustrated in Figure 1. The Operations-Centric Architecture provides the mission and the top-level construct under which the individual agency architectures are mapped with the details of the activities, services, data and technology.

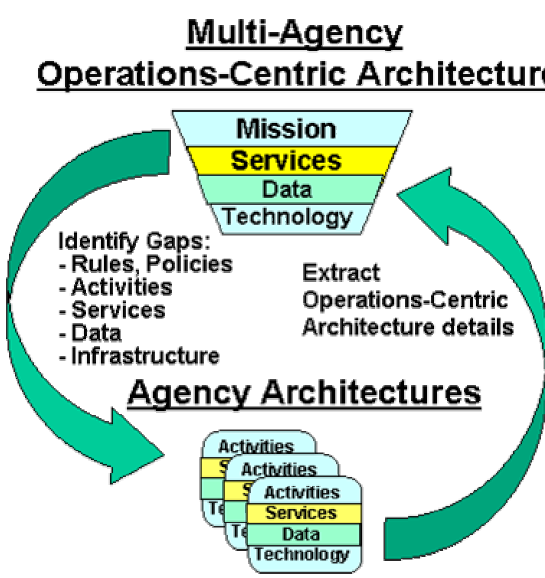

Figure 1. Relationship of Architectures

The MSR also provided a Readiness Model that describes five levels of interaction among agencies and organizations when they are tasked to support a mission. The levels of interactions in the Readiness Model range from Mission Independence where there is no common mission to Mission Integration where the missions are so closely intertwined that the different agencies should be structured into one organization. [4] Finally, the MSR also provided a web-services tool to help develop the Multi-Agency Operations-Centric Architecture by allowing users to pull together the pieces of the various agencies' architectures. [5]

The EAMA MOIE supported the Dynamic Phase of the case study by providing the methodology to generate executable architectures that could support the dynamic analysis of the Operations-Centric Architecture. The research in the MOIE focused on a single agency's architecture and how to address that agency's performance and effectiveness using executable architectures. The case study attempts to extend that capability by expanding the scope to an architecture involving multiple agencies. The MOIE provided the guidelines and rules to allow the conversion of the static Operations-Centric Architecture into an executable form in a set of simulation tools. [6]

Static Phase

The Static Phase of the case study used an Activity-based approach to develop the Multi-Agency Operations-Centric Architecture. Using the top-level mission statement, we created a generic Activity Model that captured the main set of activities for the general case of the selected scenario. We used three levels to develop the Activity Model. This follows a common structure used by organizations such as the Department of Homeland Security in its recent Universal Task List (UTL) document. [7] The Department of Defense also uses this structure in its Universal Joint Task List (UJTL). [8]

The top level activity is the mission to be accomplished. The mission is then decomposed into activities that represent the main operations that must be performed to accomplish the mission. We assign one or more agencies to perform each operation. We decompose each operation into mission essential tasks (MET) that are defined for the organizations assigned to each Operation. Typically, the MET are found within the UTL or UJTL with additional detail in the Operational Activity Model of the organization's architecture, which decomposes these tasks even further. These tasks describe the key activities that the organization must perform to accomplish its assigned missions. When the second-level Operations were mapped to the appropriate Mission Essential Tasks for the assigned agency, we inserted the appropriate portion of the agency's Activity Model and built the Operations-Centric Activity Model for the scenario. Figure 2 shows the construct of an Operations-Centric Activity Model.

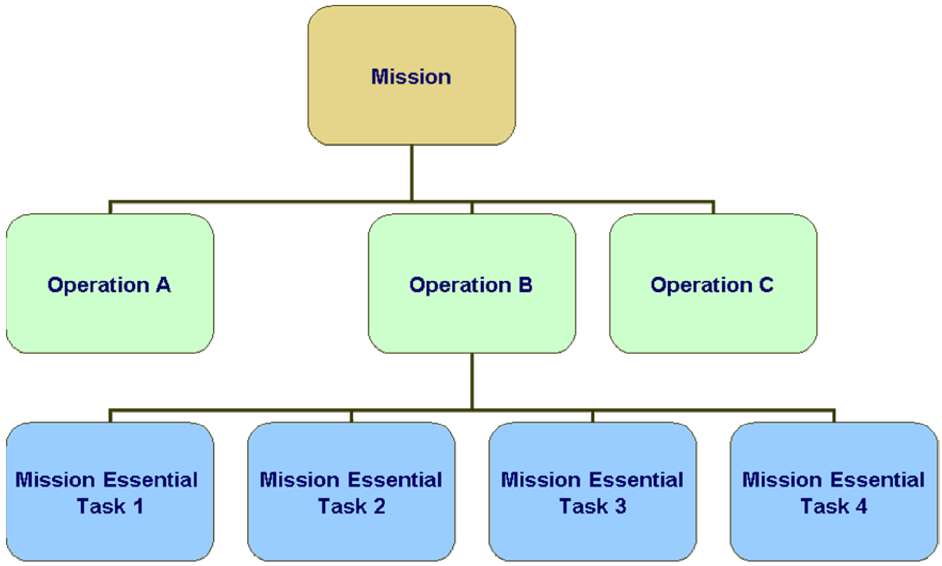

Figure 2. Operations-Centric Activity Model

The next part of the Static Phase was to conduct a Gap Analysis to identify which parts of the Architecture were missing. This occurred when we were unable to find an individual agency's architecture to execute an activity in our generic Activity Model. There were a number of possible reasons for gaps in the model. First, the agency identified to perform the activity might not have the activity included as part of its current architecture even though it should have. Second, there may not be any agencies identified in the original organizational structure to accomplish this activity. Third, there may be no agencies that had this activity identified as part of their mission. To resolve any gaps, the headquarters in charge of the overall mission must identify if any agency that is currently part of the mission can fill the gap and if the agency has the available resources to perform the activity. If this is not possible, the headquarters must determine if a new agency is required to perform the activity. Any changes should be reflected in an updated Operations-Centric Architecture. Obviously, these gaps must be filled while still in the planning phase of the operation.

After the Gap Analysis was completed, we conducted an Overlap Analysis. This analysis identified the cases where more than one agency is identified to perform an activity. The analysis should address several issues including, if it is necessary for these agencies to perform the same activity. It may be a matter of insufficient resources in one agency and thus, one or more additional agencies are needed to supplement the primary. Another issue to address is whether these agencies are using different procedures to perform the activity. If they are, some investigation is needed to determine if these differences might create problems in the execution of the mission, perhaps by confusing other participating agencies who are expecting one procedure when a different procedure is actually used.

After the Architecture is completed and vetted, we can move on to the Dynamic Phase of the case study.

Dynamic Phase

The Dynamic Phase consists of several modeling efforts to put the key components of the Operations-Centric Architecture into an executable form, i.e., in a simulation environment.

The first effort is to model the scenario in an operational environment simulation, or scenario driver. In a military environment, this would be a combat simulation. The underlying concept is to represent all the key entities (units, agencies, people, sensors, weapons systems, vehicles, aircraft, and vessels) in their appropriate terrain and environment (air, land, sea, weather conditions, etc.) to show how events and interactions among these entities would occur. To model this correctly, maps, entity icons, movement routes, and actions must be developed in the scenario driver. We used a tool called Joint Military Art Command Environment (JMACE) as the scenario driver. [9]

The second modeling effort is to import the key business processes from the Architecture into a process modeling tool. One option is to import all business processes into one tool. Another option is to divide up the business processes among different tools so that the processes of one type agency (e.g., DoD) are in one tool and the processes of another type agency (e.g., DHS) are in another tool. This provides some flexibility as well as providing the realization that different agencies will likely use different tools to model their architectures. We used a tool called Bonapart as the process modeling tool. [10]

The third effort is to model the communications networks in a network modeling tool. The network model allows the calculation of any delay times in passing data due to the load on the communications network and the capability of the systems to send and receive data in the proper format with the appropriate communications means. We used NetSim (NS-2) as the communications network modeling tool. [11]

After capturing the architectures in these simulations, we linked the simulations into a High Level Architecture (HLA) federation. The HLA federation manages the sharing of object attributes across the simulations and synchronizes the time among the simulations so that they stay at the same simulation time until all simulations are ready to advance.[12]

Conducting the Analysis

After running the simulations, we conducted an analysis of the simulation runs to determine the performance and effectiveness of the architecture. The analysis consisted primarily of examining output from JMACE and Bonapart to determine the measures of force effectiveness (MOFEs), the measures of effectiveness (MOEs) and measures of performance (MOPs) from the simulation run. Our MOFEs from JMACE included how well the agencies accomplished their assigned missions. The MOEs in Bonapart included the overall process time for each business process. The MOPs in Bonapart included the time required to conduct an activity in a business process and the utilization of resources (human and system). The MOPs in NS-2 included the delay time between nodes.

By determining these measures, we can determine if the business processes are occurring in a timely manner, and if the agencies executing the mission are achieving the desired objectives. Additionally, with a full scale representation of the OPLAN, including all resources and activities, we could examine other organizational issues such as the over- or under-utilization of critical resources. For example, we may have discovered through the analysis that when the operation reached a certain level of intensity, the resources of one of the agencies had reached its limits. At this point, the agency would need the support of the other agencies that can perform the same operation. Further analysis of the scenario may also indicate that changes are needed in the organizational structure or the assignment of operations. This is representative of the type of analysis that can be accomplished with this capability.

Insights and Lessons Learned

The research challenges encountered along the way, while limiting the scope of the study, provided a number of valuable insights and lessons learned from the effort. The primary challenges were the limitations in the architecture products that were available and the shortcomings of the simulation tools that were available for the scenario we used.

There are several insights lessons learned gained through this case study that apply to both the architecture and the planning communities within agencies.

Lack of Architecture Maturity, Consistency and Content

There are critical shortcomings in organizations' architectures that prevent them from easily integrating with other organizations' architectures to create a mission operations-centric architecture.

This is understandable as the architectures are generally constructed for the more limited purpose of Capital Planning and Investment Control (CPIC). Although the work performed in this research is directed at adding capabilities for a more robust application of architectures to operations planning and analysis, these added capabilities will also make for more effective performance-based CPIC applications.

Having gone through a practical exercise of trying to assemble the right pieces of architectures from organizations to analyze the operational performance of mission organizations and supporting information services, several things are clear. First, these architectures generally lack a level of maturity and consistency to allow them to be integrated as part of a larger architecture.

Second, these architectures lack a reasonable level of mission, business, and technical detail to allow the type of modeling and simulation required to execute a scenario involving multiple agencies. The level of detail of the operational activities and information being passed between activities is insufficient to model the actions required by the OPLAN. Significant additional modeling is required to support the proper representation in the simulations.

Third, most of the architectures lack the complete set of activities related to the scenario we examined in the case study. Even when related activities could be identified, they lacked the fidelity of definition required to identify the resources employed. Although a particular agency was supposed to be performing certain activities in the operation, those activities did not appear in the agency's architecture or, the description of an activity was too general to really apply it to the model.

One area that has not been addressed between the architecture community and the operational community is how architectures support required operational documentation such as an Operations Order (OPORD) or an Operations Plan (OPLAN). As the architecture domain matures and we gain a greater understanding of how to apply architectures, there must be a merger of terminology and structure captured in architectures with the scenario specific information of an OPORD or OPLAN. Operational Activities, Operational Nodes, Information Exchanges, and Event Traces from architectures must help organizations flesh out their OPLANs and OPORDs. This is the basic concept of an Operations-Centric Architecture.

Additionally, well-developed architectures can assist in identifying what needs to be changed in terms of organization, processes and capabilities. In DoD, this is typically described in terms of solutions in the areas of Doctrine, Training, Leadership Development, Organization, Materiel, Personnel, and Facilities (DTLOM-PF). By examining various parts of an architecture, potential solutions in one of the DTLOM-PF areas may emerge. For example, we can determine if Doctrine needs some changes by examining the Operational Nodes, the Operational Activities performed at those nodes, the Human Roles performing the activities, and the Information passed among the activities. An examination of these components provides insights into problems with the processes employed, utilization of resources, and Tactics, Techniques and Procedures (TTP) for the organization. Another example is to examine the linkage between the Human Roles and the Systems those humans are using to address the requirements and possible shortcomings in Training.

Architecture Interoperability

Multi-agency modernization environment adds significant complexities for which current architectures are inadequate. Architectures are currently being developed in an isolated environment, i.e., there is no clear attempt to proactively develop the architectures to support integrating them with other architectures to represent a multi-agency, operations-centric architecture. The complexity of a multi-agency environment is not being captured in the individual architectures that must comprise the multi-agency architecture for that environment. This hampers attempts to integrate these architectures and to conduct any significant analysis of their capability, performance, and effectiveness in accomplishing the mission.

Architectures must be developed with the understanding that they must interoperate with many other architectures. Terminology, naming conventions, and notation standards for architectures must be established to ensure compatibility when integrating architectures from different sources. Just as notation standards have been established for building architecture blueprints, similar standards are needed for IT architecture documentation that will facilitate a common understanding of architectures developed in different frameworks or by different architects.

Approach to Performance Analysis

The EAMA approach offers a potential methodology to conduct performance analysis as addressed by the OMB-FEA Performance Reference Model (PRM). [13] We demonstrated an approach to performance analysis that implements essential features of the PRM. The PRM outlines a general approach to measuring and assessing performance, but it also recommends that this approach be 'operationalized' for the specific environment of the agencies involved. This research operationalizes the performance aspects of the multiple agencies involved in one scenario for the homeland security domain. The application of executable architectures to multi-agency operations allows us to address the gaps and overlaps among the architectures being integrated to support the multi-agency mission. By identifying the gaps, we can determine any shortcomings of the agencies tasked to accomplish a common mission. By identifying the overlaps, we can determine potential opportunities where duplicate effort may occur, or where differences in processes by agencies performing similar tasks may cause operational problems in execution. Performance analysis must include a capability to conduct a dynamic analysis of the architecture in question. Executable architectures provide a logical approach to dynamic analysis.

Conclusion

The major conclusion is that the Multi-Agency Executable Architecture approach, coupling a Multi-Agency Operations-Centric Architecture with dynamic simulation, can provide a robust framework for complex multi-agency modernization and operations planning. By adding a dynamic analysis capability to the toolkit, architects can examine and assess their architectures to determine if they adequately support a multi-agency mission. Likewise, those in the operational world can use executable architectures to examine and assess their OPLANS to determine if they have any critical shortcomings.

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