

Current State of Capability-based System of Systems Engineering in Korea Ministry of National Defense

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Abstract. This paper surveys the concept of Capability Based Assessment (CBA), System of Systems (SoS) and Enterprise Architecture (EA). Also, we present EA based weapon SoS capability assessment approach in a conceptual way. Then we suggest some technical issues in order to further develop EA based SoS capability assessment methods.

Keywords: Capability Based Assessment; System of Systems; Enterprise Architecture;

1 Introduction

Capability Based Assessment (CBA) is an analysis process to validate the requirements of joint warfighting. The CBA assesses operational risks associated with the gaps. The CBA is used to provide decision makers with information about capability gaps between future objectives and current capabilities, alternatives of material and/or non-material to resolve the gaps, and probabilities to succeed a given operation mission. System of Systems (SoS) is an emerging research field. Although the concept of SoS has been around some times, the concept has not been fixed completely. Recently, US DoD defined the concept of SoS as an aggregation of independent systems to achieve some objectives, and published System Engineering Guide for SoS to address SoS engineering considerations. An aggregated weapon systems with interoperability to perform military operations mission is a typical SoS. The capabilities of weapon SoS should be assessed for the military operations and requirements generated from capability gaps. Performance is one element of a weapon SoS capabilities. And then weapon systems have their architecture including capability data such as performance, exchangeable data and external interface profiles.

Therefore, EA based weapon SoS capability assessment can perform more quantitative CBA by comparing future SoS required system performance from legacy system architecture data. This paper suggests EA based weapon SoS capabilities assessment approach in a conceptual way and introduces some technical issues for the future EA based SoS assessment methods.

2 Related Works

2.1 Capability Based Assessment

The US Joint Capabilities Integration and Development System (JCIDS) is a process to validate the requirement of joint warfighting. The primary objective of the JCIDS process is to ensure that the capabilities required by the joint warfighter are identified with their associated operational performance criteria in order to successfully execute the missions assigned [1]. Capability Based Assessment (CBA) is the first step among 4 steps, the other 3 steps compose of Approval of Initial Capabilities Document (ICD) and Courses of Action, Approval of Capability Development Document (CDD) and Approval of Capabilities Production Document (CDP).

The CBA identifies: the capabilities and operational performance criteria required to successfully execute missions; the shortfalls in existing weapon systems to deliver those capabilities and the associated operational risks; the possible non-materiel approaches for mitigating or eliminating the shortfall, and when appropriate recommends pursuing a materiel solution. Current US DoD thrust is to use the CBA to both identify gaps and help advise which particular gaps require action, and not attempt to dictate detailed solutions, otherwise, there would be no way to give recommendations on what to do [2]. The CBA analytical process contains The Study Definition Phase; The Needs Assessment Phase; The Solutions Recommendations Phase and the Opportunity-Based CBA. At these phase, capability analyst can answer several key questions:

- Define the mission
- Identify capabilities required
- Determine the attributes/standards of the capabilities
- Identify gaps
- Assess operational risk associated with the gaps
- Prioritize the gaps; identify and assess potential non-materiel solutions
- Provide recommendations for addressing the gaps

Korea the Joint Chiefs of staff also published the CBA guidebook which is considering the jointness from Requirement Planning for top down requirement generation based future capability. They have defined Joint Capability Area and Joint Task List for the standard taxonomy. And they have applied M&S, experiment, Multiple Logistic Regression(MLR) to analyze capabilities. However, the main manner is the qualitative way that is decided by Subject Matter Experts (SME). If quantitative manners like weapon system performance are added to present ways, more scientific capability analysis could be achieved.

2.2 System of Systems

A System of Systems is a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities [3].

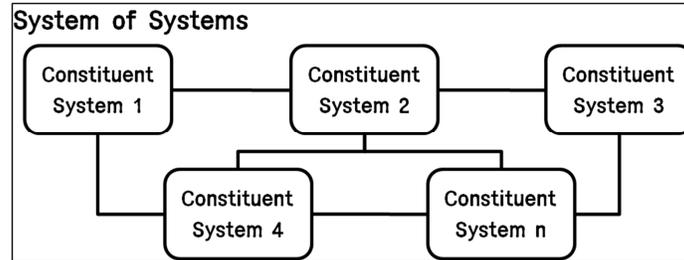


Fig. 1. System of Systems

According to [4], there are four types of SoS.

- Virtual : Virtual SoS lack both a central management authority and centrally agree upon purposes. Large behavior emerges, and may be desirable, but the super system must rely upon relatively invisible mechanisms to maintain it.
- Collaborative : Collaborative SoS are distinct from directed systems in that the central management system organization does not have coercive power to run the system. The constituent systems must, more or less, voluntarily collaborate to fulfill the agreed upon central purpose. The internet is a collaborative system.
- Acknowledged : Acknowledged SoS have recognized objectives, a designated manager, and resources for the SoS; however, the constituent systems retain their independent ownership, objectives, funding, and development and sustainment approaches. Changes in the systems are based on collaboration between the SoS and the system.
- Directed : Directed SoS are those in which the integrated system-of-systems is built and managed to fulfill specific purposes. It is centrally managed during long-term operation to continue to fulfill those purposes, and any new ones the system owners may wish to address.

Another SoS reference is an advanced transportation system. There is an enduring global need for the efficient transportation of people and goods across land. Worldwide trends such as increasing populations, urbanization, economic uncertainty, climate change, and susceptibility to loss from man-made and natural events are placing stress on existing land-based transportation systems and capabilities. At the same time, the world is moving and functioning faster through the use of the internet, cell phones, computers, and the telecommunications networks that enable the transmission of these digital signals. All of this has placed new challenges, opportunities, and complexity on our capacity to transport ourselves and sustain economic development. Land transportation in the 21st century must address such challenges, take advantage of the opportunities, and reduce or contain the complexity. To achieve these results will require the application of a system of systems approach that unifies existing, diverse transportation modes and systems into a functioning whole, optimizes their operations, and enables future capability growth to respond to national, regional, and local needs [5].

Standards are important, defining elements of the interfaces for SoS. Standards must also be managed over the life of the system to ensure they continue to be

enablers for system interoperability and performance. Standards that are locally imposed will be the easiest to manage over time whereas more broadly used standards will require existing or new standards-governing bodies to add, modify, or delete standards to address evolving requirements and technologies [5]. This reference shows applying SoS Approach of US Smart Grid case too.

Above two SoS references emphasize SoS architecture include data items - constituent system, system function, system relationship, data flow and communication, technical standards.

2.3 Enterprise Architecture

Architecture is the structure of components, their interrelationships, and the principles and guidelines governing their design and evolution over time. Enterprise Architecture (EA) is a strategic information asset base, which defines the mission, the information necessary to perform the mission and the technologies necessary to perform the mission, and the transitional processes for implementing new technologies in response to the changing mission needs [6].

The DoDAF Meta-model provides information needed to collect, organize, and store data in an easily understandable way, and the presentation description of various types of views provide the guidance on how to develop graphical representations of that data that will be useful in defining acquisition requirements under the DOD Instruction 5000-series [3].

EA uses to improve the business effectiveness and efficiency and to control planning and investment [7] and to improve business performance and productivity [8] EA encompasses system performance, interface, technical interface data, which can be used in assessing capabilities of weapon SoS performing military operations that is the most important business in military.

In Korea MND, there is Enterprise Architecture Management Process such as Fig. 2. They have built EA for information systems interoperability by MND-AF ver 1.2 which is similar to DoDAF ver 1.0. The MND EA composes of high level information system EA and information systems architectures. The MND EA is stored and managed in Architecture Repository which is designed specified in MND-AF Meta Data Model. And the stored architecture data is reused during other information systems development.

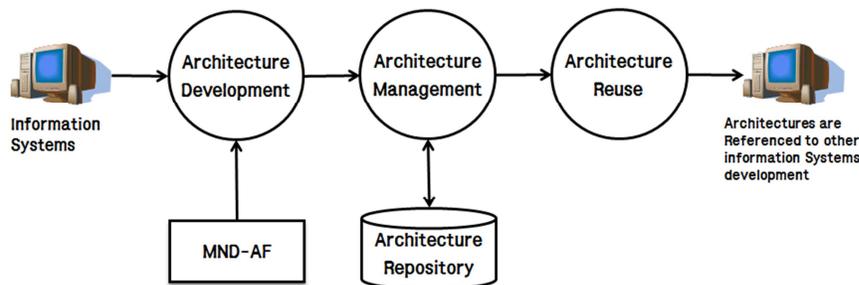


Fig. 2. Current status of MND EA management process

MND architecture management system in Fig.2 has some limitations for CBA. MND-AF ver 1.2 doesn't encompass capability concept while it is including in the latest DoDAF or UK MoDAF. So the architects are difficult to describe their architecture with capability concepts. And the authority of the Architecture Repository should have a tool to validate the quality of the submitted architecture when registering it in Repository System. It is difficult to review the consistency check of the architectural products relationships by only manual means. Also stored architecture data is scarcely used for decision making processes because of lack of relevant policies and technical supports.

3 EA based SoS Capability Assessment Approach and related Technical Issues

Some weapon systems are composed of SoS to achieve a mission objectives. Required capabilities of this SoS are needed to be assessed for deciding whether it can achieve the mission or not by CBA. EA can present weapon system performance, interface, and technical standard profile data for assessing SoS performance capabilities. This chapter suggests an approach to assess weapon SoS capability based on EA, and lists down some technical issues to use CBA.

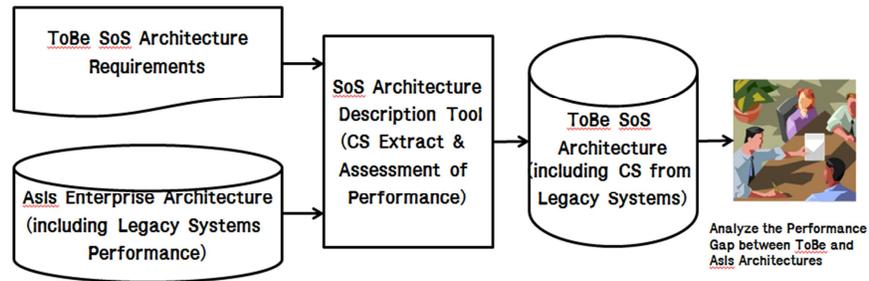


Fig. 3. EA based CBA approach

Fig.3 shows EA based CBA approach in conceptual model level. ToBe SoS Architecture Requirements are specified with the tasks, their processes, performance criteria, and information exchange requirements among them. SoS Architecture Tool can extract and assess Constituent Systems proper to the SoS task requirements performance among legacy systems in EA. With this approach that considers the object of CBA to SoS, CBA authority can more easily describe ToBe SoS architecture using EA and could quantitatively understand the gap of future capability from current weapon systems.

For the purpose of such EA based CBA, some issues are :

- Defining Standard Taxonomies for architecting
 - Need to standardize terminologies which are used in architecting
 - For example, Capability, System, Task, Performance, Data, System function, Technical standard, etc

- If standardization is too difficult for architects to comply with the standards and think to prevent expression freedom, ontology may be considered to an alternative. It is an advanced technology for computer machine to be able to understand the terminology meaning, when systems use different terms even though same meaning.
- Developing model for quantitatively measurable capability assessment
 - Need to develop assessment models for quantitative element in capabilities.
 - For example, assessment model using weapon system range, whether exchange data between systems or not etc.
- Managing Syntactically and Semantically Qualified EA data
 - Need to validate whether architecture description include all data for capability assessment
 - Need to assess architecture description comply with Standard Taxonomy and Architecture Meta Data syntactically and semantically

4 Conclusion

In this paper, we presented the concept of Capability Based Assessment (CBA), System of Systems (SoS) and Enterprise Architecture (EA). Also, we presented EA based weapon SoS capability assessment approach in a conceptual way. Then we suggested some technical issues in order to further develop EA based SoS capability assessment methods. We expect to be able to improve quantitative CBA technology and SoS engineering, and expand EA data usage to variety areas.

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