Enterprise Architecture Reference Models: A Shared Vision for Service-Oriented Architectures

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Abstract – *The business- and mission-driven objectives of service-oriented architectures depend on the dynamic interaction of collaborative integrated operations in a federated operational environment. The theme of this paper is that integrated operations can and should be considered service-oriented nodes in a dynamic information environment. In the Department of Defense, this dynamic information environment has often been referred to as "the global information grid" or simply "the grid." We describe enterprise architecture reference models as a dynamic abstract reference environment for net-centric collaboration between the service-oriented "nodes on the grid." The complex, dynamic interaction of service-oriented nodes in the net-centric environment creates an opportunity to view enterprise architecture as a taxonomy of well-defined systems architectures governed by a set of enterprise architecture reference models.*

Keywords: architectural frameworks, enterprise architecture, enterprise architecture reference models, federal enterprise architecture, global information grid, information environment, net-centric operations and warfare, reference models, nodes, service-oriented architecture, and systems architecture.

1 Introduction

The Department of Defense (DoD) Global Information Grid (GIG) is an information environment composed of interoperable computing and communications components [1]. Recently advances in service-oriented architectures[1] (SOAs) have caused SOAs to gain traction [2] as Chief Information Officers (CIOs) begin to think about Web Services as an enabler of their mission-critical capabilities. As the DoD transforms toward the notion of the GIG, increased emphasis is being given to SOAs as enablers to enhance mission performance and reduce information technology costs in the DoD. There is a direct association between SOAs and the concept of federated business/mission services this paper refers to as "nodes on the grid." illustrated in Fig. 1. These service-oriented "nodes on the grid" correspond to the notion of federated operations in the horizontal data fusion model [3,4].

This paper discusses how enterprise architecture (EA) reference models (RMs), when properly constructed, can provide an important governance model for managing information technology for federated operations in federated environments. In contrast, this paper also discusses system-centric architectural frameworks and, when properly used, can be well suited for governance and management of integrated operations in environments where it is important to have systems highly integrated and tightly coupled.

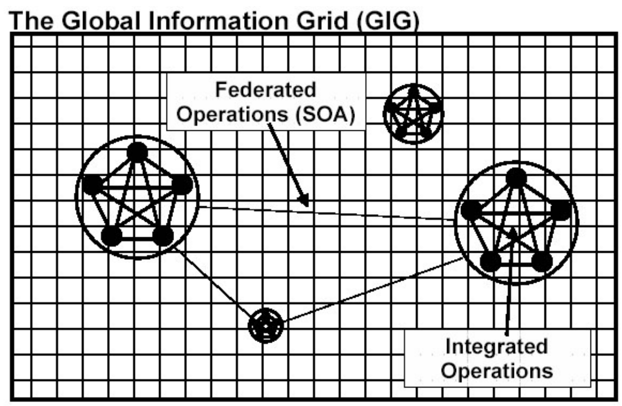

Fig. 1. GIG EA Service-Oriented Architecture (SOA)

In this paper, we also briefly review system-centric architectural frameworks and an emerging DoD net-centric reference model along with a set of DoD EA reference models. The net-centric reference model can provide technical direction to those who are developing a net-centric operations and warfare operating environment, while the DoD EA RMs provides a unifying concept and an abstraction of the GIG EA that will allow both capital planners and program managers in the DoD to move together in a shared vision toward the transformation goals of the DoD. The discussion of system-centric architectural frameworks and the use of net-centric reference models elaborates on our theme that system-centric architectures tend to work well for describing the details of "nodes on the grid" in a federated service-oriented enterprise architectures, i.e., the GIG EA.

[1]Service-Oriented Architecture (SOA): An architecture built around a collection of reusable components with well-defined interfaces [2]

2 Integrated & Federated Operations

There are many well-developed architectural frameworks that provide a common language and lexicon for information technology architects to describe and build system architectures. The rapid expansion of service-oriented architectures [2] in a net-centric environment like the GIG creates both opportunities and challenges for system-centric architectural frameworks. System-centric architectural frameworks tend to promote closed, well-defined integrated operations and are governed by single administrative domains. The span of these administrative domains are often congruent to the notion of "nodes on the grid." System-centric architectural frameworks that work well for integrated operations tend to constrain the stated benefits of federated architectures in the net-centric environment. Net-centric architectures tend toward open, loosely coupled, service-oriented interactions between integrated operational systems.

The benefits of service-oriented architectures in the net-centric environment are congruent with the benefits found in the concept of large service-components on the grid where these large service-components ("nodes on the grid") perform business or mission services similar to those that might be offered today in e-business or e-government environments. System-centric architectures resemble an integrated assembly of smaller system components within the large service-component construct. These system-centric architectures provide benefits appropriate to the requirements of more tightly integrated communities.

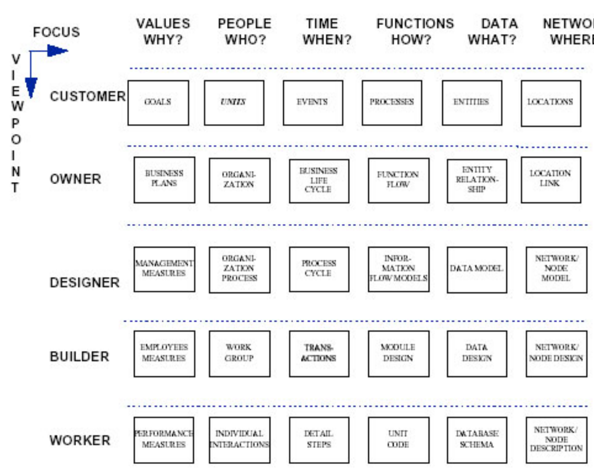

Fig. 2. Zachman Framework for Information Systems

There are many well-established architectural frameworks and methodologies available for the systems engineer. The list includes well-known frameworks, such as the Zachman Framework [5], the Spewak Methodology [6], the DoD Architectural Framework (DoDAF) [7], the Federal Enterprise Architecture Framework (FEAF) [8], and the Treasury Enterprise Architecture Framework (TEAF) [9]. All of these frameworks and methodologies were constructed to support the development of information systems architectures.

J. A. Zachman is considered by many experts in the field of enterprise architecture to be an early pioneer of information systems architectural frameworks. The Zachman Framework, illustrated in Fig. 2, is a two-dimensional matrix of 30 cells covering the Who, What, Where, When, Why, and How questions of an "enterprise." The "enterprise" is then split into six perspectives, starting at the highest level of business abstraction and iteratively decomposed to system implementation. S. A. Spewak elaborated on the Zachman Framework by expanding on how Zachman depicted architectural planning and organization.

The DoDAF is an information systems architectural framework that describes information systems in the context of integrated military operations. The DoDAF has evolved over the years from the C4ISR Architecture Framework to include both military and business operations. The FEAF was established in 1999 by the CIOs in response to the 1996 Clinger-Cohen Act mandating that Executive Agencies develop and maintain an information-technology enterprise architecture. The TEAF was developed by the Department of the Treasury in response to numerous government directives, including the FEAF. The TEAF has numerous perspectives derived from the Zachman Framework.

Popkin Software supports all of the above information system architectural frameworks in their *System Architect®* software [10]. According to Popkin, System Architect is "a repository based, flexible, and comprehensive modeling tool geared toward supporting enterprise architecture frameworks." An interesting observation to keep in mind is that these frameworks, methodologies, and tools are documented and designed to be applied at any level in the systems development process. These frameworks, if applied as designed, greatly facilitate systems development.

However, those frameworks, methodologies, and tools do not necessarily optimize the governance of federated information environments, like the GIG. Emerging service-oriented architectural concepts, reference architectures, and reference models are examples of other architectural concepts that require a frame of reference that is a higher level of abstraction than system-centric architectures. Without these higher-level abstractions, how can capital planners influence the diversity of myriad loosely coupled "nodes on the grid" that are administered by numerous autonomous organizations and entities? How can executives govern without high level abstractions for understanding the "big picture"? And, how can analysts inform the decision-making processes without high-level abstractions through which they communicate? In addition, what are appropriate governance models for the cooperative collaboration between interdependent nodes in the information environment and are these higher level abstractions useful for those purposes?

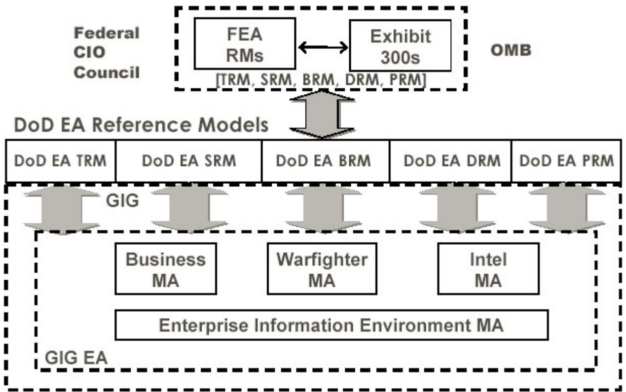

Fig. 3. Emerging DoD EA Reference Models

In DoD, the DoD EA RMs (Fig. 3) are emerging as high-level abstraction of the GIG EA that provide a unified view of the GIG EA that may be useful for capital planning, architectural analysis, and informing managerial and executive decision processes. Enterprise management operations extend from internally focused to externally focused operations in which the DoD is one component of the U.S. Federal Government's enterprise architecture.

The concept for the GIG EA RMs was derived from the emerging Federal Enterprise Architecture (FEA) [11], which today consists of a set of reference models. The FEA is discussed in the next section.

3 Federal Enterprise Architecture

The Office of Management and Budget (OMB) has been working with the Federal CIO Council to develop an FEA—a business-based framework for government-wide improvement envisioned to facilitate efforts to transform the federal government to one that is citizen-centered, results-oriented, and market-based. The FEA is being constructed through a collection of interrelated reference models designed to facilitate cross-agency analysis and the identification of duplicative investments, gaps, and opportunities for collaboration within and across federal agencies [11].

The FEA models, illustrated in Fig 4, are defined as:

- Performance Reference Model (PRM)
- Business Reference Model (BRM)
- Service Component Reference Model (SRM)
- Data and Information Reference Model (DRM)
- Technical Reference Model (TRM)

The FEA PRM is designed to measure the performance of major information technology initiatives and their contribution to program performance [12]. The FEA BRM is the foundation of the FEA, designed to describe the federal government's lines of business [13]. The SRM is a service-component -based reference model that is envisioned to provide, independent of business function, a foundation to support the reuse of applications, application capabilities, service-components, and business services [14].

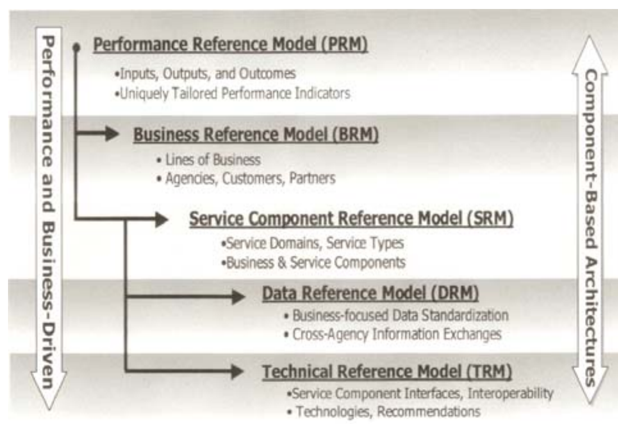

Fig. 4. FEA Reference Models

The FEA DRM and TRM, as illustrated in Fig 4, support the FEA SRM. The TRM is designed to provide a foundation to describe the standards, specifications, and technologies supporting the secure delivery, exchange, and construction of federal service-components [15] in a service-oriented architecture. The FEA DRM, currently under development, will facilitate cross-agency exchange of information.

An interesting observation is that the foundation of the FEA reference models and the notion of the GIG information environment are based on the notion of large (business) mission-driven service-components communicating on an information grid. This common thread can be developed in conjunction with the shared capital planning and improvement goals of both the FEA and the DoD to derive the concept of a set of emerging DoD EA RMs congruent to the FEA. However, before turning our attention to EA RMs, we briefly discuss another DoD reference model, the Net-Centric Operations and Warfare (NCOW) RM.

4 NCOW Reference Model

The NCOW reference model represented the target view of the DoD's GIG information environment. This objective view was a service-oriented, inter-networked, information infrastructure where users request and receive services that enable operational capabilities across the range of: (1) military operations, (2) DoD business operations, and (3) department-wide enterprise management operations [16]. The SOA nature of the NCOW RM is illustrated in Fig. 5.

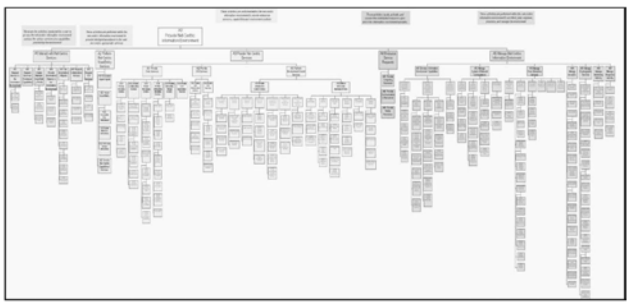

Fig. 5. NCOW Reference Model Node Tree

The stated purpose [17] of the NCOW reference model is to describe the evolving DoD enterprise aspects of an objective net-centric information environment for the GIG. The NCOW reference model, as designed, serves as a common, enterprise-level, reference model for the DoD's net-centric operations and for current and future acquisition programs to reference. The NCOW reference model enables a shared vision of the DoD enterprise information environment and is used to assist decision-makers promote enterprise-wide unity of effort. The stated NCOW reference model objective [17] is to perform program development and oversight with a uniform, department-wide reference architecture. Information-technology-related issues can be addressed within individual programs and across the set of enterprise programs in a constructively consistent, coherent, and comprehensive manner.

The NCOW reference model describes the activities required to establish, use, operate, and manage the net-centric information environment at the enterprise level to include the generic user-interface, the intelligent-assistant capabilities, the net-centric service capabilities, and enterprise net-centric management components. Although acknowledged, the richness of core functional enterprise services, or Community of Interest (COI) functional enterprise services, are excluded from the NCOW reference model. These core functional enterprise services are left to the functional community and/or the COI to develop and describe. For example, functional enterprise services for the Business Mission Area (MA), Intel MA and Warfighter MA (as shown in Fig. 3) are left to MA to describe. The NCOW reference model also identifies a selective set of key standards that will be needed for evolving NCOW capabilities to support the GIG.

The NCOW reference model node tree, illustrated in Fig. 5, was designed to assist technical personnel and architects understand the characteristics of the GIG net-centric environment and the sharing of information in the Enterprise Information Environment MA. The value proposition of services that are provided by systems are enhanced when the services and information provided by complex systems are shared across the enterprise. We view net-centric federated systems as nodes of large system components that can be illustrated in a service-oriented architectural construct via a set of enterprise architecture reference models.

The NCOW reference model illustrates a high-level view of large federated service-components. The reference model elaborates on the user interaction with the net-centric environment and the core enterprise services to enable the information environment for DoD communities of interest. In addition, the NCOW reference model describes the resourcing and management of net-centric services in the information environment.

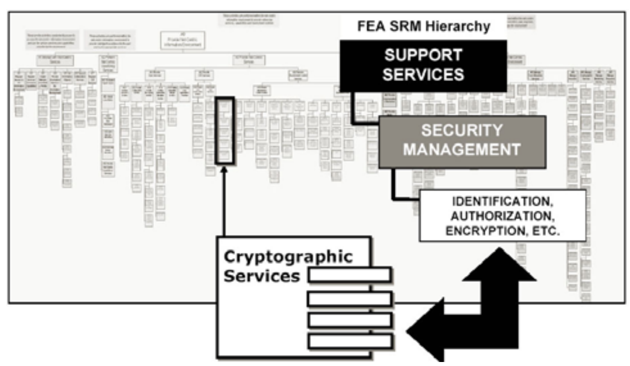

Fig. 6. Notional FEA SRM – NCOW Node Tree Mapping

Figure 6 illustrates a notional FEA SRM mapping to the NCOW node tree. The emerging NCOW reference model is a work-in-progress [18] that provides a shared enterprise architectural construct for the federated operation of large service-components on the grid or "nodes on the grid." These large service-components in DoD are considered to be nodes in the GIG. The reference model also provides a framework to develop technical direction for GIG nodes that are under the administrative control of semi-autonomous programs and organizations. A shared vision of net-centricity articulated in the form of an enterprise architecture reference model could facilitate the cooperative federation of myriad integrated system architectures across the federal government.

5 DoD EA Reference Models

The concept of the DoD enterprise architecture reference models, illustrated earlier in Fig. 3, is an emerging governance model useful for capital planning purposes for the GIG EA. Our country recently experienced and observed grid behavior that created catastrophic failures when grid components were tightly integrated. Engineers understand that a federated approach to the complex electric grid improves services to the citizens. Utility components can be viewed as interdependent autonomous nodes on the power grid that require a shared governance and capital planning model.

We believe that the concept of large interdependent autonomous service-components and the cooperative governance issues required by the power grid seem directly applicable to the FEA and DoD EA RM concepts for governance and resourcing large service-components on the information grid. Conclusions that can be drawn about the recent power grid failure that has applicability to the governance and capital planning issues facing DoD and the federal government at large are discussed in the following paragraphs.

One conclusion from observing the power grid failure, which has applicability to this discussion, is that systems architectural frameworks designed for developing integrated operations are not necessarily the best choice for developing federated service-oriented architectures. The DoD EA RMs are an example of a shared vision using large service-components on an information grid. These service-components have large granularity and can be viewed from the perspective of SOA.

Another conclusion is that systems architectural frameworks are important tools for the development of integrated system "nodes on the grid":

For purposes of discussion clarity, we define a *system* as:

> ***system***: n. a group of interacting, interrelated, or interdependent elements forming a complex whole that is well defined with predictable behavior under a single administrative authority.

The above system definition is derived from the Internet definition of an *autonomous system:*

> ***autonomous system (AS)***: n. the unit of router policy, either a single network or a group of networks that is controlled by a common network administrator (or group of administrators) on behalf of a single administrative entity (such as a university, a business enterprise, or a business division).

In the Internet world of exterior routing, autonomous systems are the world's largest routing entities. The Internet is a confederation of these autonomous routing entities or domains, commonly known as Internet service providers. The loose interaction between myriad desktop users on the World Wide Web and the services they desire is very different from the tight interaction and scheduling expected in more tightly integrated systems.

Large enterprise service-oriented architectures can be effectively developed when the enterprise is viewed as federations or confederations of autonomous service providers ("nodes"). The emerging concepts of net-centric enterprise architecture reference models simply convey the notion of interdependent federated autonomous services—"nodes on the grid," primarily for capital planning purposes.

Therefore, the purpose of enterprise architecture reference models is to provide a set of reference models that facilitate the dynamic cooperative interaction of autonomous service providers. However, the functionality of this interaction should not be expected to have the same reliability and quality of service of a well-defined, tightly-integrated system because the service-oriented federation will be used for both enterprise capital planning and investment control (CPIC) and to guide the enterprise planning of the GIG EA.

We elaborate on the practical use of these concepts in the next sections by discussing quality of service considerations and a notional planning model for a set of EA RMs in terms of the DoD EA RMs, the FEA, and emerging DoD GIG EA.

6 Quality of Service Considerations

When discussing net-centric architectures it is appropriate to consider the general notion of Quality of Service (QoS). There are three general textbook QoS classifications: hard real-time, soft real-time, and non-real-time scheduling [19].

Hard real-time QoS is often defined as scheduling that must occur as designed or there will be a catastrophic failure(s) including the loss of human life. Examples of hard real-time scheduling include sensor-to-shooter military targeting, air-traffic control processes, and similar integrated operations.

Soft real-time QoS is often defined as scheduling that must occur as designed, or there will be a degradation of service. Voice and video communications are examples of soft real-time requirements where momentary network outages or congestion result in a degradation of service quality; however, the loss is not catastrophic. Using a Web browser to retrieve information is appropriately considered a soft real-time or non-real-time requirement.

There are many researchers working on methods to solve hard real-time scheduling problems in the net-centric information environment. However, the current state-of-the-practice of store-and-forward networks, combined with the fact that the Internet is a confederation of autonomous systems, creates a logical structure for net-centric federated architectures vis-à-vis system-centric integrated architectures. Table 1 illustrates this logical structure.

Table 1. QoS Scheduling for the Different Environments

	Net-Centric (Federated)	**System-Centric (Integrated)**
Hard Real-Time	Experimental	Best Practice
Soft Real-Time	Maturing	Established
Non-Real-Time	Best Practice	Overkill

The QoS table summarizes an important concept in the evolution of net-centric architectures. We suggest that, for the immediate future, it may not be economically feasible nor practical to expect the net-centric information environment to perform hard real-time scheduling services that are traditionally provided by tightly-integrated architectures. This means that hard real-time requirements are, based on current trends, better suited (for both economic and technical reasons) for system-centric integrated architectures.

On the other hand, the trend for soft real-time and non-real-time scheduling is a trend toward the net-centric information environment. The net-centric environment is envisioned to be more dynamic, agile, and economical. These are also the characteristics of soft and non real-time scheduling requirements. Hard real-time scheduling requirements are better suited for system-centric integrated architectures. It follows then that system-centric architectural frameworks are well suited for hard real-time scheduling requirements.

The notion of QoS helps us define the enterprise architects view of net-centric information architectures: Confederations and federations of autonomous organizations that have soft real-time and non real-time scheduling requirements are well suited for the net-centric information environment.

7 Notional Net-Centric Planning

The notional planners' view of EA RMs, the GIG EA, and relationship between the FEA RMs is illustrated in Fig. 3. The DoD EA RMs mutually inform the FEA and the mission area architectures within the DoD, including the Core Enterprise Information Environment Mission Area, Business Mission Area, the Warfighter Mission Area, and the Intel Mission Area.

Figure 3 illustrates, at a high level, that:

- OMB, in collaboration with the Federal CIO Council via the FEA, informs the CPIC for the Federal Government.
- OMB requires that Executive Agencies to align with the FEA via the BRM, SRM, TRM, DRM, and PRM.
- DoD EA RMs align with the FEA reference models to mutually inform the DoD and the Federal information environment.
- DoD systems architects use the DoD EA RMs to inform DoDAF views [7] that describe large GIG service-components or "nodes on the grid."

The objective service-components are "in the large" and the granularity of service-components in the DoD EA RMs are therefore, large federated business service-components as described in the SOA literature [2]. The service interfaces of "in the large" service-components are paramount, not the details of the integrated systems behind the service-component interfaces.

The notional planning model presented is not complete; it is a work-in-progress based on ongoing collaborations between systems architects and net-centric enterprise architects. There is also considerable collaboration between enterprise architects and CPIC specialists. These ongoing collaborations will further refine the notional planning model for DoD EA RMs and the relationship between federated operations and integrated operations, illustrated in Fig. 1.

8 Concluding Remarks

It is appropriate to note that net-centric reference architectures, i.e., the DoD EA RMs, do not intend to define an integrated systems architecture because the GIG is not a system *per se*. The GIG is a *net-centric information environment* that facilitates the interaction of GIG users with GIG services. This indicates that traditional integrated systems architectures do not define the GIG, but they can and do define the systems design of the large service-oriented "nodes on the grid".

Therefore, we offer that enterprise architectures for vast, complex organizations, like the DoD and the federal government, require hybrid enterprise architectural approaches that facilitate the dynamic collaboration and cooperation of federated operations with integrated operations. The FEA and DoD EA RMs share this common objective vision.

Enterprise architectures have design tradeoffs and give-and-take requirements. It is a common mistake to envision that all the requirements of enterprise architectures can be equally met by all stakeholders. Finding the right balance, the right level of interaction, the right layer of service-component granularity, the right governance models, and other attributes are enormously complex challenges at the Federal and DoD level.

One of the obvious net-centric planning challenges is to avoid designing hard real-time interactions between federated service-components that explicitly attempt to mimic well-defined hard real-time systems behavior. We suggest in this paper is that when the information exchange or processing requirements necessitate the reliability and predictability of hard real-time integrated systems architectures, then planners should not expect to explicitly mimic that system's performance or capability in the federated net-centric information environment for the immediate future.

Obtaining the appropriate hybrid granularity between the net-centric information environment and the systems-centric integrated environment continues to be very challenging. We suggest that there is a tremendous amount of critical and objective thought that needs to be continued to develop the state-of-the-practice. We hope this paper helps further that practice and stimulates other work in this interesting area.

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References

[1] *"Capstone Requirements Document – Global Information Grid,"* Commander in Chief, Joint Forces Command, US Department of Defense, March 28, 2001.

[2] Datz, T., *"What You Need to Know About Service-Oriented Architecture*," CIO Magazine, January 15, 2004.

[3] Stenbit, J. P., *"Horizontal Fusion: Enabling Net-Centric Operations and Warfare*," Crosstalk: The Journal of Defense Software Engineering, January 2004.

[4] Bass, T., *"Service-Oriented Horizontal Fusion in Distributed Coordination-Based Systems,* Submitted to Elsevier Journal of Information Fusion, October 2003.

[5] Zachman, J. A., *"A Framework for Information Systems Architectures,"* IBM Systems Journal, Volume 26, Number 3, 1987.

[6] Spewak, S. H., *"Enterprise Architecture Planning: Developing a Blueprint for Data, Applications, and Technology,"* John Wiley & Sons, 1992.

[7] "*DoD Architectural Framework Version 1.0*," John Stenbit, 2004.

[8] *"Treasury Enterprise Architecture Framework,"* Department of the Treasury, Chief Information Officer Council, Version 1, July 2000.

[9] *"Federal Enterprise Architecture Framework,"* Chief Information Officer Council, Version 1.1, September 1999.

[10] Popkin Software, Inc., *"Enterprise Frameworks,"* http://government.popkin.com/, September 2003.

[11] *"Federal Enterprise Architecture (FEA),"* http://www.feapmo.gov/, September 2003.

[12] *"The Performance Reference Model Version 1.0: A Standardized Approach to IT Performance,"* FEA Program Management Office, September 2003.

[13] *"The Business Reference Model Version 2.0: A Foundation for Government-wide Improvement,"* FEA Program Management Office, June 2003.

[14] *"The Service Component Reference Model Version 1.0: A Foundation for Government-wide Improvement,"* FEA Program Management Office, June 2003.

[15] *"The Technical Reference Model Version 1.1: A Foundation for Government-wide Improvement,"* FEA Program Management Office, August 2003.

[16] Osterholz, J.L., *"Net-Centric Operations & Warfare Reference Model,"* ASD/NII, Office of the CIO, Department of Defense, July 2003.

[17] *"Overview and Summary Information (AV-1),"* NCOW Reference Model (NCOW RM) Draft, DoD CIO, ASD/NII, Version 0.9, July 2, 2003.

[18] *"Net-Centric Operations and Warfare Reference Model (NCOW RM) FAQ,"* DoD CIO ASD/NII, Version: 1, 30 September 2003.

[19] Deng, Z., and Liu, J. W.-S., *"Scheduling Real-Time Applications in an Open Environment,"* Department of Computer Science, University of Illinois at Urbana-Champaign, May 14, 1997.

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