



EVALUATION OF ENTERPRISE ARCHITECTURE

INTEROPERABILITY

Graduate Systems Engineering Capstone Project

Theresa A. Jamison, Major, USAF

Phillip A. Layman, Major, USAF

Brice T. Niska, Major, USAF

Steven P. Whitney, Major, USAF

AFIT/ISE/ENY/05-J02

**DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY**

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio



The views expressed in this capstone report are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government.

EVALUATION OF ENTERPRISE ARCHITECTURE INTEROPERABILITY

Graduate Systems Engineering Capstone Project

Presented to the Faculty

Department of Aeronautics and Astronautics

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the
Degree of Master of Science in Systems Engineering

Theresa A. Jamison, Major, USAF

Phillip A. Layman, Major, USAF

Brice T. Niska, Major, USAF

Steven P. Whitney, Major, USAF

AFIT/ISE/ENY/05-J02

June 2005

ABSTRACT

Currently Department of Defense (DoD) policy requires programs to develop architectural products as part of programmatic documentation. Specifically, the Joint Capabilities Integration and Development System (JCIDS) and DoD 5000 series requires architecture products at acquisition milestone decisions. The DoD implements a recommended framework, the Department of Defense Architecture Framework (DoDAF), which describes these architectures.

The purpose of this project, suggested by Air Force Space Command, was to examine the value of existing analytical tools in making an interoperability assessment of individual enterprises, as well as assess the touch-points between enterprise architectures. This novel evaluation scheme is based solely on the architecture products, rather than the more common assessment via interviews of subject matter experts or actual system testing. If the architecture products required by DoD are to have any merit, their underlining data must be used by decision makers. Well developed architectures can better aid in capability planning, investment decisions (i.e. spiral upgrades), as well as support proposals for integrated Family of Systems solutions by identifying gaps.

The project examines the application of two different assessment tools to three different enterprise architectures; these included the DoD's Global Information Grid (GIG), the Air Force C2 Constellation (C2C) and the Combatant Commanders Integrated Command and Control System (CCIC2S). Lastly, some suggested recommendations for improving both the architectural products and tools to aid in interoperability assessments.

ACKNOWLEDGMENTS

We would like to thank our advisor Lieutenant Colonel John Colombi for his support and guidance. Despite the initial frustrations in the early going, he remained upbeat and confident we would deliver a good product. Several of the lessons taught during his Systems Architecture course found relevance in our project. In addition, we would like to thank Dr. David Jacques, the Department Head for systems engineering, his systems engineering course was the beginning of our adventure. The final person from AFIT we would like to thank is Captain Chad Millette, whose thesis on the Department of Defense Architecture Framework (DoDAF) Implementation was a starting point for our efforts.

There were a variety of people from across the Air Force that helped us with development of this project and its objectives. Specifically, we would like to thank Joanne Schissel, Sandi Harrison, David Lund, Major Brad Hawk, and Lieutenant Colonel Gustavo Hernandez from Air Force Space Command; Major Todd Wiest from the Electronic Systems Center; Jill Johnson, Dr. Alok Das, and Yolanda King from the Air Force Research Laboratory; and finally, Lieutenant Colonel Patrick Frankes, Paul Popejoy, and Mike McGee from the National Security Space Office for their support in scoping our project.

The last group of people we would like to recognize is our families for putting up with us and helping us along this past year as we returned to school after long breaks since our previous educational opportunities. Our spouses and children were our constant support, safety net and relief systems. They never allowed us to get too wrapped up in our studies nor forget the more important things in life.

TABLE OF CONTENTS

ABSTRACT.....	iii
ACKNOWLEDGMENTS	iv
TABLE OF CONTENTS.....	v
LIST OF FIGURES	vii
LIST OF TABLES.....	vii
1 Introduction.....	1
1.1 Background and Project History.....	1
1.2 Purpose.....	2
1.3 Research Objective	2
2 Literature Review.....	3
2.1 Overview.....	3
2.2 Policy	3
2.3 Definitions.....	7
2.3.1 Enterprise Architectures.....	7
2.3.2 Integration Points	8
2.3.3 Interoperability.....	9
2.4 Description of the DoDAF.....	10
2.5 The Enterprise Architectures	13
2.5.1 Command and Control Constellation (C2C).....	13
2.5.2 Combatant Commanders Integrated Command and Control System (CCIC2S)	14
2.5.3 Global Information Grid (GIG)	15
3 Tools	17
3.1 The Levels of Information System Interoperability (LISI).....	17
3.1.1 LISI Interoperability Maturity Model.....	18
3.1.2 LISI Attributes	19
3.1.3 LISI Reference Model.....	21
3.1.4 LISI and the DoDAF.....	22
3.1.5 LISI Shortcomings	23
3.1.6 InspeQtor Tool.....	25
3.2 Enterprise Architecture (EA) Score Card	25
3.2.1 EA Score Card Aspect Areas.....	26
3.2.2 EA Score Card Advantages and Disadvantages	28
3.3 Comparison of LISI and EA Score Card	30
4 Methodology	32
4.1 EA Score Card Methodology.....	32
4.1.1 Assumptions and Constraints.....	33
4.2 LISI Methodology and Implementation Issues.....	33
5 Results of Analysis	35
5.1 EA Score Card Analysis	35
5.1.1 C2C EA Score Card Analysis.....	36
5.1.2 CCIC2S EA Score Card Analysis.....	39
5.1.3 GIG EA Score Card Analysis	42
5.2 LISI Analysis	45

6	Results of System to System Analysis.....	46
6.1	EA Score Card Comparisons	46
6.1.1	Conclusions.....	54
6.2	LISI Results and Conclusions.....	55
6.3	Findings.....	55
6.4	Recommendations for Further Study	58
6.4.1	New Tool for Measuring Interoperability.....	58
6.4.2	The Role of eXtensible Mark-up Language (XML) in Architecture Documents	59
6.4.3	Determining the Right Number of Architecture Views.....	59
6.4.4	Comparing Architecture Design Methodology – Object Orientated versus Structured Analysis.....	60
6.4.5	Sensitivity analysis for EA Score Card Results.....	60
7	Bibliography	61
8	Vita.....	64
8.1	Major Jamison.....	64
8.2	Major Layman.....	64
8.3	Major Niska	65
8.4	Major Whitney	65
	Appendix A: EA Score Card Results.....	67
	References.....	71

LIST OF FIGURES

Figure 1: JCIDS Documents/NR-KPP Products Matrix (CJCSI, 2003).....	5
Figure 2: Integration Points	9
Figure 3: The LISI Interoperability Maturity Model	18
Figure 4: The <i>PAID</i> Attributes Puzzle	19
Figure 5: LISI Reference Model	22
Figure 6: LISI Relationship to the DoDAF Views	23
Figure 7: Zachman Framework.....	28
Figure 8: The Enterprise Architecture Score Card Example	30
Figure 9: Comparison of LISI Interoperability Attributes and EA Score Card Aspect Areas	31
Figure 10: C2C Score Card Results	37
Figure 11: CCIC2S Score Card Results.....	40
Figure 12: GIG Score Card Results	43
Figure 13: Comparison of Contextual Levels.....	47
Figure 14: Comparison of Environmental Levels.....	48
Figure 15: Comparison of Conceptual Levels	49
Figure 16: Comparison of Logical Levels	50
Figure 17: Comparison of Physical Levels.....	51
Figure 18: Comparison of Transformational Levels.....	52
Figure 19: Comparison of All Levels	53
Figure 20: Past Interoperability Assessment Methodology	57
Figure 21: Today's Net-Centric Assessment Methodology	57
Figure 22: Proposed Net-Centric Interoperability Methodology.....	58

LIST OF TABLES

Table 1: The DoDAF Views	12
Table 2: C2C Architecture Views Provided	14
Table 3: CCIC2S Architecture Views Provided	15
Table 4: GIG Architecture Views Provided.....	16
Table 5: Extended Enterprise Architecture Framework	26
Table 6: C2C Results	36
Table 7: C2C Predominate Views Used in Score Card Analysis	36
Table 8: CCIC2S Results.....	39
Table 9: CCIC2S Predominate Views Used in Score Card Analysis	39
Table 10 GIG Results.....	42
Table 11 GIG Predominate Views Used in Score Card Analysis.....	43
Table 12: C2C EA Score Card Results	67
Table 13: CCIC2S EA Score Card.....	68
Table 14: GIG EA Score Card Results	69

1 Introduction

1.1 Background and Project History

Initially this effort began on a much different path, investigating the possibility of developing an initial architecture supporting responsive space, sponsored by the Air Force Research Lab (AFRL). During the research of the problem it was discovered that Air Force Space Command (AFSPC) had several initiatives underway, with several products soon to be delivered. Additionally, a meeting with representatives from the National Security Space Office (NSSO) provided focus towards the development of a responsive space architecture at the national level. Following this meeting with the NSSO, the possibility of the capstone project adding value to either AFRL or the NSSO was the first shift in direction.

It was during the investigation of responsive space where the idea of investigating enterprise architectures to support the NSSO strategic effort came to light. Following a meeting with AFSPC/DRN, the investigation of Air Force Space Command enterprise architectures began to take shape. AFSPC posed several questions, one of which was, “Explain what it means to integrate enterprise architectures, and define test criteria for judging the quality or degree of architecture integration.”¹ As the literature search and brainstorming continued, the drive was for conducting an interoperability examination of several architectures. The problem was scoped upon the idea of comparing the interoperability of architectures using two existing architecture evaluation tools, each developed for different purposes.

1.2 Purpose

The purpose of this project is to use three enterprise architectures to examine existing tools to make an assessment on the potential for characterizing interoperability across architectures. In doing this, the ground rules are to only utilize existing architecture products and determine if they contained sufficient information to make an assessment. This approach is counter to the more common technique of conducting extensive surveys or interviews of subject matter experts (SME). SMEs may have their own biases which often times differ from the published documentation of the system.

1.3 Research Objective

In light of DoD 5000.1 requirement for interoperability of information systems, the focus is on examination of three architectures for interoperability from an enterprise perspective. The three architectures are the Combatant Commanders Integrated Command and Control System (CCIC2S) from Air Force Space Command, the Command and Control Constellation (C2C) from Electronic Systems Center, and the Global Information Grid (GIG) from the Department of Defense. The two existing tools, Levels of Information Systems Interoperability's InspeQtor and the Enterprise Architecture Score Card were created to examine individual architecture, but both discuss the ability to characterize system interoperability. While conducting the literature review, it appeared that most assessments of architectures or systems were conducted through some type of interview. The project goes the other way in looking at architectures as stand-alone products, because the SMEs may not always be working with the system. The objective was to assess the interoperability of the architectures through the use of existing analytical tools for making a judgment on the interoperability of architectures. The desired outcome is identifying possible tools which help in the

decision process by making an interoperability assessment across systems. Nevertheless, due to the subjective nature of this assessment, some actual systems interoperability testing may be required to validate these recommendations.²

2 Literature Review

2.1 Overview

This section covers an examination of DoD policy, some definitions key to the remainder of the project, a review of the architecture framework and an overview of the three architectures being examined. A synopsis of the two tools utilized in this project is covered in the next section of this paper.

2.2 Policy

Recently systems engineering and architectures have received a renewed emphasis within the Air Force. One indication of this comes from Dr James Roche, Secretary of the Air Force in a 24 June 2002 *Air Force Times* article. In response to questions dealing with recent acquisition program problems he stated “Increasingly, I’m convinced that the systemic problem is in the field of systems engineering.”³ In fact, senior Air Force Leadership recently adjusted developmental education for its officers to provide an increased focus on systems engineering.

Moving up a level in the DoD hierarchy, architectures are an important element of the relatively new Joint Capabilities Integration and Development System (JCIDS) process. This is the joint process for identifying and resolving gaps in military capability. In terms of formal policy, Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170.01D, *Joint Capabilities Integration and Development System Instruction* and CJCSI 6212.01, *Interoperability and Supportability of National Security Systems, and Information*

Technology Systems directly impact program managers and engineers in program offices. CJCSI 3170 establishes the policies and procedures for “a joint concepts-centric capabilities identification process.”⁴ The JCIDS calls for specific DoD Architecture Framework (DoDAF) architecture views as annexes to documents such as the Initial Capability Document (ICD), Capability Development Document (CDD), and Capability Production Document (CPD) to support acquisition milestone decisions on moving forward with system development programs. Additionally, CJCSI 6212 “details a methodology to develop interoperability Key Performance Parameters...based on the format and content of the integrated architecture products described in the most current version of the DoDAF.”⁵

Beyond the JCIDS requirements, programs are required to produce architectures as part of the required documentation for Information Support Plans (ISPs – formerly C⁴I Support Plans) and as part of the documentation required to identify net-ready key performance parameters (NR-KPP).⁶ Figure 1 identifies the architecture views required for support of various documents in the JCIDS process and the use in deriving the NR-KPP. Of note is the column on the far right of the table requiring systems to have different levels of completeness in the Levels of Information System Interoperability (LISI) model, which is one of the tools discussed later to measure interoperability. According to Chairman Joint Chiefs of Staff Instruction (CJCSI) 6212.01C, “all CDDs (Capability Development Documents) that exchange information will have a NR-KPP” which is “derived from a completed architecture and developed from” mandatory architecture products. In fact, the instruction goes on to say “development of the NR-KPP begins with designing the architecture for the proposed system.”⁷

Document	Net-Ready Key Performance Parameter Products													MCO/ RM	KIP Compliance	IA Compliance	LISI Profile		
	Supporting Architecture Products																		
	AV-1	OV-1	OV-2	OV-3	OV-4	OV-5	OV-6C	SV-1	SV-2	SV-3	SV-4	SV-5	SV-6					TV-1	
ICD		X													X				
CDD	X		X		X	X	X				X	X	X	X	X	X	X	X	X Basic
CPD	X		X		X	X	X				X	X	X	X	X	X	X	X	X Complete
CRD		X		1		2									2	2	2		
ISP	3	3	3		3	3	3	3			3	3	3	3	3	3	3	3	3 Complete

Note: X = Required

(1) Old CRDs Updates

(2) New CRDs

(3) ACAT, NON ACAT and Fielded Systems. NR-KPP products produced for the CDD and CPD will be used in the ISP.

Figure 1: JCIDS Documents/NR-KPP Products Matrix (CJCSI, 2003)

All of these development programs are budgeted, programmed and financed through the DoD's Planning, Programming, Budgeting and Execution (PPBE) System. Originally, PPBE was introduced in the 1960's by then Secretary of Defense Robert McNamara to create DoD budgets that better achieve Department objectives via integration of the information necessary to craft effective plans and programs. This system is the primary DoD resource management system to articulate strategy; identify force size, structure, and equipment; set programming priorities; allocate resources for operations, acquisition, and other functions within fiscal constraints; and evaluate actual outputs against planned performance, adjusting resources as appropriate. It was modified slightly by Secretary Rumsfeld in 2003 to reflect current budgeting practices. The PPBE reflects the current status of today's programs, in essence if the program does not have funds allocated in PPBE it does not exist.

The DoD followed this rationale in conducting a Net-Centric Program Assessment in the summer of 2004. The stated purpose of this assessment was “to help components and programs with the Net-Centric Operations Warfare Reference Model, and to establish priorities and design transition plans for embracing the spirit and intent of Global Information Grid (GIG) Enterprise Services.”⁸ The results of the assessment were then to be used by the DoD Chief Information Officer (CIO) to assist in departmental deliberation of resource allocation input into the President’s Budget for Fiscal Years 2006-2011.

Coming back to the service level, the Air Force’s rationale for insisting on improved systems engineering comes from the increasing complexity, sophistication, and cost of current weapon systems programs, an issue for systems engineering help to guide the program through development. Howard Eisner offers the following in his book, *Essentials of Project and Systems Engineering Management*, “Architecting a large-scale complex system is the centerpiece of systems engineering.”⁹ The AFIT course on Systems Architectures presented the view that architectures are necessary when doing new and complex things. For example, one would not hire an architect to build a house in a development, but would if they were branching out to build something that had not been done before. Following this analogy, the system architecture serves as a blueprint for the program and within the acquisition process, “systems architecting is an essential part of the system engineering process and relies on many of the methodologies that have been developed over time.”¹⁰

2.3 Definitions

2.3.1 Enterprise Architectures

Basically enterprise architecture explains the business processes, relationships, guidance and policy that characterize the environment in which an organization exists. Maier and Rechtin, in their work the *Art of System Architecting*, say an enterprise specification of an Open Distributive Processing system is a model of the system and the environment with which the system interacts. It covers the role of the system in the business, and the human user roles and business policies related to the system. The enterprise viewpoint is a viewpoint on the system and its environment that focuses on the purpose, scope, and policies of the system.¹¹

Two other definitions for 'enterprise' during are pre-told. The first comes from John Zachman's *Concept for Framework for Enterprise Architecture, Background, Description and Utility*. Zachman's work states that set of descriptive representations (i.e. 'models') that are relevant for describing an enterprise such that it can be produced to management's requirements (quality) and maintained over the period of its useful life (change). The second view comes from the Federal CIO Council which claims enterprise architecture describes the "target" situation that the organization wishes to create and maintain.¹²

Perhaps the benefits of Enterprise Architectures as explained in an article by David Brown in spring 2000 will help put things in context. The benefit of understanding an organization's enterprise architecture is to create a more efficient organization; not just a bunch of disparate, individually efficient functions, which are, organizationally dysfunctional.¹³

The bottom line is an Enterprise Architecture is different from simple system architecture in that it does not focus specifically on a single system and has a broader scope, an overarching vision and concern for the management and business practices of the organization. While a simple architecture may capture the development of a system or lead to requirements definition for a new acquisition, the Enterprise Architecture incorporates the external systems environment of the organization, fielded systems and development activities. Like a simple architecture, an Enterprise Architecture can decompose into a system of systems or family of systems.

2.3.2 Integration Points

Integration points are defined as the interfaces between two systems at the external systems level. Applying this to the systems engineering model from Buede's text, *Engineering Design of Systems Models and Methods*, leads to the picture in Figure 2. Integration points can evolve from information flows (control, input and/or output signals) and possibly the physical interactions (mechanisms) between systems. It is important that integration points must be commonly defined across separate architectures. their scale and deconstruction may vary by architecture. For example, portfolio management architectures need not include as many views as one used for technology investment decisions. An operations planning and execution architecture should include all seven operational views but may only need one or two systems views, compared to a systems design and development architecture which needs more systems views than operational views.¹⁴ However, integration points *cannot* contradict each other. Finally, integration points provide a common core for joint program payoff in JCIDS products by ensuring interoperability and reuse.

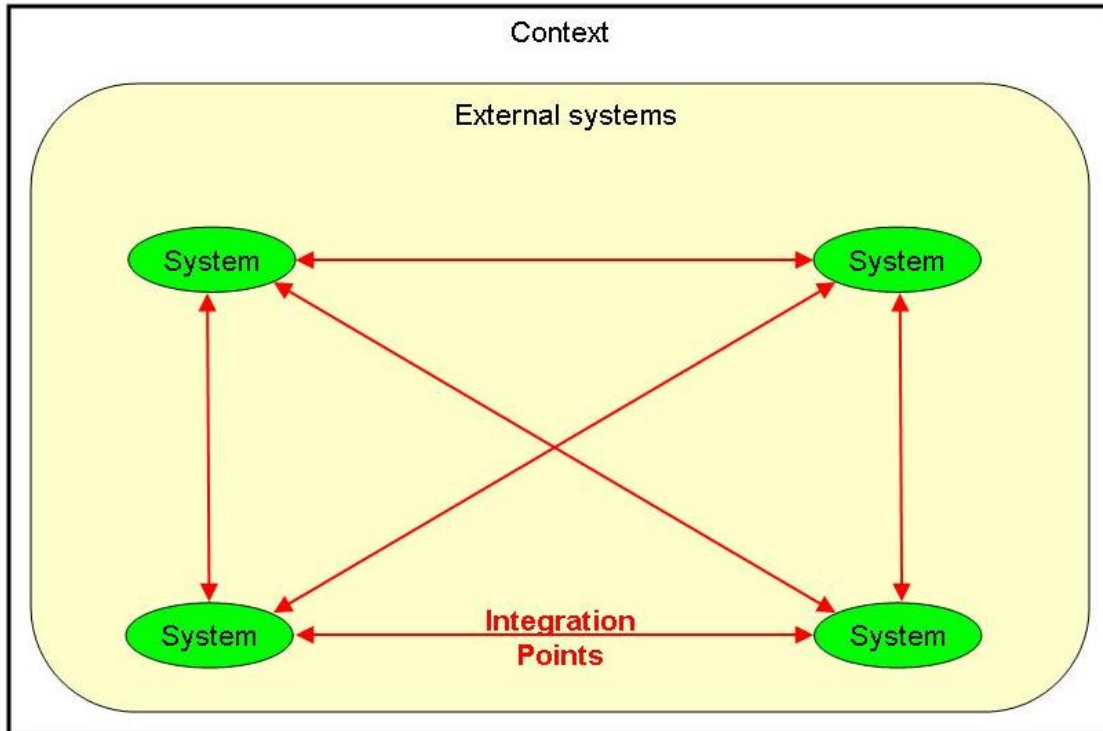


Figure 2: Integration Points

2.3.3 Interoperability

Interoperability takes on many different meanings to different people. For the purposes of this project, interoperability is the connectivity of two systems to flow information freely from one to another and back again.

In terms of formal policy, Chairman of the Joint Chiefs of Staff Manual (CJCSM) 3170.01a, *Operation of the Joint Capabilities Integration and Development System* defines interoperability in relation to the Net-Ready Key Performance Parameters (KPP) as “the ability of systems, units or forces to provide data, information, materiel and services to and accept the same from other systems, units or forces and to use the data, information, materiel and services so exchanged to enable them to operate effectively together. IT and NSS interoperability includes both the technical exchange of

information and the end-to-end operational effectiveness of that exchanged information as required for mission accomplishment.”¹⁵

2.4 Description of the DoDAF

A better understanding of what architecture is can be demonstrated by a discussion of frameworks. As previously mentioned, these architecture products are part of a certain framework, such as the Federal Enterprise Architecture Framework, The Open Group Architecture Framework, the IEEE 1471 Standard, the Zachman Framework, or the DoD Architecture Framework (DoDAF). Each of these frameworks is slightly different with somewhat different products recommended by each. The key framework for the analysis is the DoDAF developed “in the early 1990s [as] an architecture framework for Command, Control, Communications, Computing, Intelligence, Surveillance, and Reconnaissance (C4ISR) systems.”¹⁶ A short discussion on the DoDAF is applicable, particularly for the reason that this framework is most applicable to Air Force System Engineers. Additionally, all three architectures used in this capstone project utilize the DoDAF.

Captain Millette outlined the views of the DoDAF in his thesis with the following discussion.¹⁷ The DoDAF consists of multiple products known as views. There are four types of views, the All Views, Operational Views, Systems Views, and Technical Standards Views. Several of these views are collected in what is called an “integrated architecture” referred to extensively in the JCIDS documentation. These views are summarized in Table 1, and are the architecture products referred throughout this research effort.

DoDAF Volume Two defines architecture products as: Those graphical, textual, and tabular items that are developed in the course of gathering architecture data, identifying their composition into related architecture components or composites, and modeling the relationships among those composites to describe characteristics pertinent to the architecture's intended use.¹⁸

Thus, architecture products can take the form of Power Point charts, Excel spreadsheets, tables, and charts, as well as any other graphical product that conforms to the standard above. The DoDAF is careful not to specify a certain development methodology. In fact, it is purposely intended to be methodology independent.

The All Views category captures essential overview information about the architecture. The Overview and Summary (AV-1) is essential for documenting the assumptions, constraints, and limitations that may affect high-level decision processes involving architecture. AV-1 also identifies the approving authority, the completion date, and records level of effort and costs required to develop the architecture as well as the time frame covered and the organizations that fall within the scope of the architecture.¹⁹

“The Operational View (OV) describes the tasks and activities necessary to successfully perform the mission, the participating nodes, and the associated information exchanges.” Further, “OV descriptions are useful for...defining the operational requirements to be supported by resources and systems” and “a pure OV is materiel independent.”²⁰ In order to deliver a weapon system, the tasks and activities modeled in the OVs are allocated to systems, which are themselves modeled in Systems Views.

“The Systems View (SV) describes the systems of concern and the connections among those systems in context with the OV.”²¹ Finally, “the Technical Standards View (TV)

describes a profile of the minimum set of time-phased standards and rules governing the implementation, arrangement, interaction, and interdependence of systems.”²² The DoDAF defines an integrated architecture (a term used throughout JCIDS and other documents) as the AV-1, AV-2, OV-2, OV-3, OV-5, SV-1, and TV-1, at a minimum.²³

Table 1: The DoDAF Views

Applicable View	Framework Product	Framework Product Name	General Description
All Views	AV-1	Overview and Summary Information	Scope, purpose, intended users, environment depicted, analytical findings
All Views	AV-2	Integrated Dictionary	Architecture data repository with definitions of all terms used in all products
Operational	OV-1	High-Level Operational Concept Graphic	High-level graphical/textual description of operational concept
Operational	OV-2	Operational Node Connectivity Description	Operational nodes, connectivity, and information exchange needlines between nodes
Operational	OV-3	Operational Exchange Matrix	Information exchange between nodes and the relevant attributes of that exchange
Operational	OV-4	Organizational Relationships Chart	Organizational, role, and other relationships among organizations
Operational	OV-5	Operational Activity Model	Capabilities, operational activities, relationships among activities, inputs, and outputs; overlays can show cost, performing nodes, or other pertinent information
Operational	OV-6a	Operational Rules Model	One of three products used to describe operational activity – identifies business rules that constrain information
Operational	OV-6b	Operational State Transition Description	One of three products used to describe operational activity – identifies business processes and responses to events
Operational	OV-6c	Operational Event-Trace Description	One of three products used to describe operational activity – traces actions in a scenario or sequence of events
Operational	OV-7	Logical Data Model	Documentation of the system data requirements and structural business process rules of the operational View
Systems	SV-1	Systems Interface Description	Identification of systems nodes, systems, and system items and their interconnections with and between nodes
Systems	SV-2	Systems Communications Description	Systems nodes, systems and system items and their related communications lay-downs
Systems	SV-3	Systems-Systems Matrix	Relationships among systems in a given architecture; can be designed to show relationships of interest, e.g., system-type interfaces, planned vs. existing, etc.
Systems	SV-4	Systems Functionality Description	Functions performed by systems and the system data flows among system functions
Systems	SV-5	Operational Activity to Systems Function Traceability Matrix	Mapping of systems back to capabilities or system functions back to operational nodes
Systems	SV-6	Systems Data Exchange Matrix	Provides details of system data elements being exchanged between systems and the attributes of that exchange
Systems	SV-7	Systems Performance Parameter Matrix	Performance characteristics of Systems View elements for the appropriate time frame(s)
Systems	SV-8	Systems Evolution Description	Planned incremental steps toward migrating a suite of systems to a more efficient suite, or toward evolving a current system to a future implementation
Systems	SV-9	Systems Technology Forecast	Emerging technologies and software/hardware products that are expected to be available in a given set of time frames and that will affect future development of the architecture
Systems	SV-10a	Systems Rules Model	One of three products used to describe system functionality – identifies constraints that are imposed on systems functionality due to some aspect of systems design or implementation
Systems	SV-10b	System State Transition Description	One of three products used to describe system functionality – identifies responses of a system to events
Systems	SV-10c	System Event-Trace Description	One of three products used to describe system functionality – identifies system-specific refinements of critical sequences of events described in the Operational View
Systems	SV-11	Physical Schema	Physical implementation of the Logical Data Model entities
Technical	TV-1	Technical Standards Profile	Listing of Standards that apply to System View elements in a given architecture
Technical	TV-2	Technical Standards Forecast	Description of emerging standards and potential impact on current Systems View element, within a set of time frames

Other definitions deal with architecture’s role in the design of the system. Howard Eisner, author of *Essentials of Project and Systems Engineering Management*, believes

architecting is “fundamentally a design or synthesis process” and goes on to define architecture as “the evolution of the DoDAF.”²⁴

The DoD broadened the application of the framework beyond C⁴ISR systems based on the utility of the C4ISR Architecture Framework combined with both Federal (Clinger-Cohen Act of 1996, etc.) and DoD policy encouraging the use of architectures during program acquisition.²⁵ The result was the publication in 2004 of the DoDAF Version 1.0 Volumes I and II. The stated purpose of the DoDAF Version 1.0, is “to provide guidance for describing architectures for both warfighting operations and business operations and processes.”²⁶

2.5 The Enterprise Architectures

The focus is on examination of three architectures for interoperability from an enterprise perspective. The three architectures are the Combatant Commanders Integrated Command and Control System (CCIC2S) from Air Force Space Command, the Command and Control Constellation (C2C) from Electronic Systems Center, and the Global Information Grid (GIG) from the Department of Defense.

2.5.1 Command and Control Constellation (C2C)

The Command and Control Constellation is the U.S. Air Force's force packaging approach to optimize the Air Component and maintaining C2 and Intelligence, Surveillance and Reconnaissance (ISR) capabilities in support of Joint Operating Concepts.²⁷ The Electronic Systems Command, along with the AFC2ICRC and AF/XI, created the C2C Architecture to support C2C definition and conceptual design; support requirements development, early milestone decision reviews and concept of operation maturation; facilitate Global Information Grid architecture compliance; prototype uses of

architecture as a tool to align capital investments as required by the Clinger-Cohen Act and facilitate portfolio management at both the micro- and macro-level.

The C2C Architecture documents include both a 2005 “As-Is” Architecture and a 2012 “To-Be” Architecture. The views provided are listed in Table 2. Some views are common to both architectures (the TV-2 Technical Standards Forecast, AV-1 Overview and Summary Information, etc.) MITRE Corporation created architecture views using a Structured Analysis approach. Most views were created in Popkin’s *System Architect* software and exported to Power Point briefing slides, while other products were created with Microsoft Excel.

Table 2: C2C Architecture Views Provided

AV-1	Overview and Summary Information	OV-5	2012 Node Tree
AV-2	Integrated Dictionary	OV-6a	2005 Operational Rules Model
OV-1	2005 High Level Operational Concept Graphic	OV-6a	2012 Operational Rules Model
OV-1	2012 High Level Operational Concept Graphic	SV-4	2005 Systems Functionality Description
OV-2	2005 Operational Node Connectivity Description	SV-4	2012 Systems Functionality Description
OV-2	2012 Operational Node Connectivity Description	SV-5	2005 Operational Activity to Systems Function Traceability Matrix
OV-3	2005 Operational Information Exchange Matrix	SV-5	2012 Operational Activity to Systems Function Traceability Matrix
OV-3	2012 Operational Information Exchange Matrix	SV-9	Systems Technology Forecast
OV-5	2005 Operational Activity Model	TV-1	Technical Standards Profile
OV-5	2012 Operational Activity Model	TV-2	Technical Standards Forecast
OV-5	2005 Node Tree		

2.5.2 Combatant Commanders Integrated Command and Control System (CCIC2S)

The Combatant Commanders Integrated Command and Control System is designed to support Air Force Space Command (AFSPC), North American Aerospace Defense Command (NORAD), and U.S. Strategic Command (USSTRATCOM) with an integrated, interoperable, flexible, and cost effective capability enabling warfighters to accomplish their current and evolving missions. The purpose of the CCIC2S Operational

Architecture is to capture user and operator requirements for detailed design and test of the system. This will enable the Commanders of NORAD, USSTRATCOM and AFSPC to carry out assigned missions contained in the Unified Command Plan. The operational architecture is the methodology to integrate common functions across 34 separate operational systems and 27 different programming languages.

The CCIC2S architecture was written as a “To-Be” architecture for an unspecified date of implementation. The architecture included a comprehensive Operational Requirements Document linked to a Hypertext Markup Language (HTML)-based viewer. Architectural views and products, listed in Table 3, were created in Rational Rose software with the Unified Modeling Language following an Object-Oriented approach.²⁸

Table 3: CCIC2S Architecture Views Provided

AV-1	Overview and Summary Information	OV-6a	Use Case Specifications
AV-2	Integrated Dictionary	OV-6c	Operational Trace Sequence Diagrams
OV-1	High Level Operational Concept Graphic	OV-7	Logical Data Model
OV-2	Operational Node Connectivity Description	SV-5	2005 Operational Activity Matrix
OV-3	Operational Information Exchange Requirement (IER) Matrix		Functional Performance Requirements Mapping
OV-4	Operational Command Relationships		Technical Architecture
OV-5	Activity Diagram		Systems Operational Sequence Verb List
OV-5	Use Case Relationships Diagrams		Operational Requirements Document (ORD)
OV-5	Use Case Diagrams		

2.5.3 Global Information Grid (GIG)

The Global Information Grid provides the means for warfighters, decision makers, and policymakers to conduct and support military operations. The GIG is a physical entity – the sum of the Department’s information capabilities, systems, services, and facilities, and associated processes and personnel.²⁹ The GIG Version 2 (v2) Architecture was designed to implement Net-Centric Operations and Warfare (NCOW) for future conflicts. It serves as the initial architectural description of NCOW concepts,

terminology, and modeling. It supports the DoD Chief Information Officer's decisions and recommendations concerning Information Technology planning programming acquisition and policy. Finally, it identifies the enterprise requirements for the GIG in a net-centric environment with all programs plugging into or interfacing with the GIG.

The GIG v2 Architecture applied to three separate levels of combat operation models in Strategic, Operational, and Tactical Use Cases. The Architecture Views are listed in Table 4. All three use cases were tightly coupled together in a HTML-based viewer. Views were created with Popkin's *System Architect* software using a Structured Analysis approach.

Table 4: GIG Architecture Views Provided

Strategic Use Case		Operational Use Case		Tactical Use Case	
Secretary of Defense Force Allocation		Homeland Defense		Southwest Asia Warfighting	
AV-1	Overview and Summary Information	AV-1	Overview and Summary Information	AV-1	Overview and Summary Information
AV-2	Integrated Dictionary	AV-2	Integrated Dictionary	AV-2	Integrated Dictionary
OV-1	High Level Operational Concept Graphic	OV-1	High Level Operational Concept Graphic	OV-1	High Level Operational Concept Graphic
OV-2	Operational Node Connectivity	OV-2	Operational Node Connectivity	OV-2	Operational Node Connectivity
OV-3	Operational Information Exchange Requirements	OV-3	Operational Information Exchange Requirements	OV-3	Operational Information Exchange Requirements
OV-4	Command Relationships	OV-4	Command Relationships	OV-4	Command Relationships
OV-5	Activity Model	OV-5	Activity Model	OV-5	Activity Model
OV-5	Node Tree	OV-5	Node Tree	OV-5	Node Tree
SV-1	Systems Interface	SV-1	Systems Interface	SV-1	Systems Interface
SV-2	Systems Communications	SV-2	Systems Communications	SV-2	Systems Communications
SV-3	System Matrix	SV-3	System Matrix	SV-3	System Matrix
SV-4	System to System Functions	SV-4	System to System Functions	SV-4	System to System Functions
SV-5	System Function to Operational Activity	SV-5	System Function to Operational Activity	SV-5	System Function to Operational Activity
TV-2	Technical Standards Forecast document is common for all three Use Cases				

3 Tools

Two existing tools, Levels of Information Systems Interoperability's InspeQtor and the Enterprise Architecture Score Card were created to examine individual architecture, but both discuss the ability to characterize system interoperability.

3.1 The Levels of Information System Interoperability (LISI)

Joint Vision 2020, the vision statement for the DoD, says “interoperability is the foundation of effective joint, multinational, and interagency operations. The joint force has made significant progress toward achieving an optimum level of interoperability, but there must be a concerted effort toward continued improvement. Interoperability is a mandate for the joint force of 2020 – especially in terms of communications, common logistics items, and information sharing.”³⁰

In response to the vision of the Joint Chiefs as laid out in Joint Vision 2020, the C4ISR Architecture Working Group (AWG) delivered the Levels of Information System Interoperability (LISI) construct in 1998. The purpose of the LISI construct is to provide a process for determining interoperability needs, assessing the ability of specific information systems to meet those needs, and selecting pragmatic solutions and transition paths for achieving higher states of capability and interoperability.³¹ There are several key concepts in this construct's approach. The first is providing an interoperability maturity model to describe levels of sophistication regarding information exchanges. Next, LISI provides requirement organizations the ability to identify operational and system requirements in terms of interoperability. Third, the LISI construct has a suite of capabilities associated with the procedures, applications, infrastructure, and data domains in order to obtain the desired level of capability. Finally, LISI provides a practical assessment process for determining the interoperability of a given system or across a

system pair. This process uncovers capabilities that may be lacking in the systems, areas not compatible and options for resolving the deficiencies so the systems can move to a higher level of interoperability.³²

3.1.1 LISI Interoperability Maturity Model

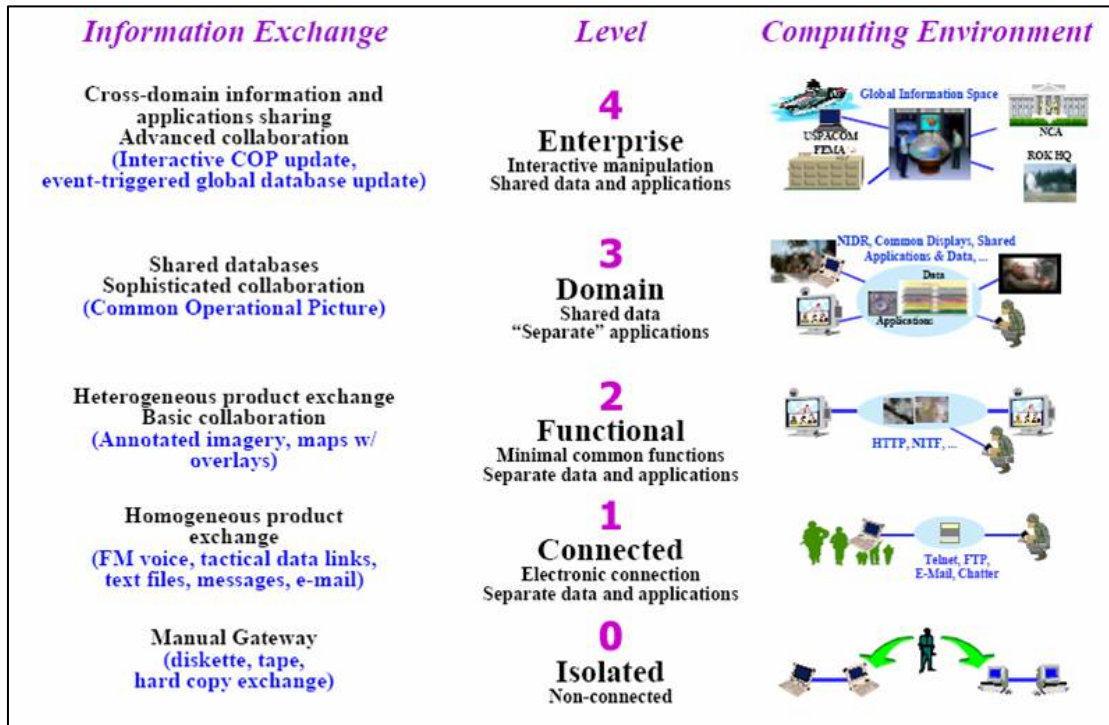


Figure 3: The LISI Interoperability Maturity Model

The LISI construct uses five increasing levels of sophistication regarding system interaction and the ability of the system to exchange and share information and services. These levels are the basis of the Interoperability Maturity Model as shown in Figure 3. Each higher level represents a demonstrable increase in capabilities over the previous level of system-to-system interaction.³³ For example, a system that shares files via an e-mail attachment would operate at a Level 1, or the connected state. That is to say the ability exists to transfer files electronically between or within the systems, but it requires

another program to make the transfer. On the other end of the spectrum a system with a common database that shares data amongst systems components would be at the Level 3 or Domain level. As it is apparent from this example, the higher the sophistication of the system, the higher the level rating in the LISI Interoperability Maturity Model and the model implies that a higher rating is the desired result. With-in these maturity levels, there are many factors which LISI groups into the four key attributes discussed in the next section.

3.1.2 LISI Attributes

This construct uses four areas of cohesion to organize the aspects of information systems. The four attributes are Procedures, Applications, Infrastructure, and Data that fit together like a puzzle, as shown in Figure 4, to describe the construct while providing the unique perspectives of purpose and identity.

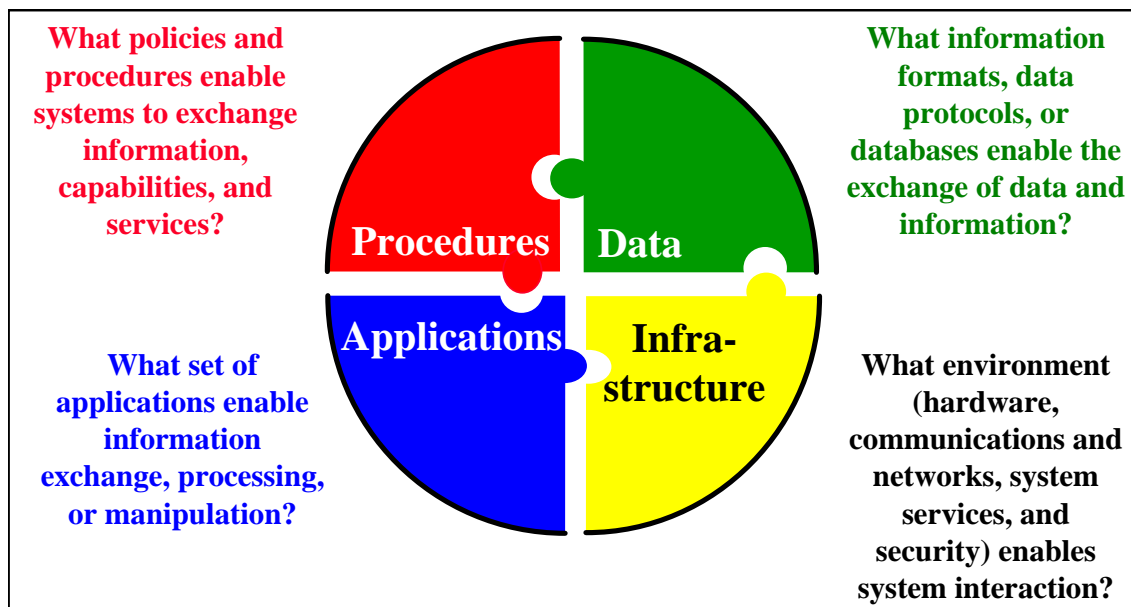


Figure 4: The PAID Attributes Puzzle

The *procedures (P)* attribute encompasses the many forms of documented guidance and operational controls, standards and architecture guidance, which affect all aspects of

system development, integration, and operational functionality.³⁴ The general purpose of the procedures attribute is to address implementation of the system's interoperability.

The four categories in procedures attribute are as follows:

- **Standards** – Compliance with existing technical standards, architectures and common operating environments
- **Management** – Covers the realm of program management from system requirements definition to delivery and turn-over of the system
- **Security Policy** – Covers the procedures to ensure that proper security is maintained while accessing and sharing information.
- **Operations** – considers the operational plans of the system, but not how the system operates. For example, if the system has plans for e-mail file transfer but the mail server is not connected, then credit is given because the system is planned to use this method.

The purpose of the *applications (A)* attribute is to cover the fundamental purpose and function for which any system is built -- its mission. Specifically this attribute examines the functional requirements specified by users to perform an operational activity and how they are handled by the software application. For interoperability to occur effectively similar capabilities or a common understanding of the shared information must exist between systems; otherwise, users have no common frame of reference.

The third attribute, *Infrastructure (I)*, supports the establishment and use of a “connection” between systems or applications. It does not matter if the connection is handled on a simple sneaker-net approach where files are transferred via magnetic media and walked from component to component, or transferred via complex integrated

wireless networks. There is also a security aspect involved in this attribute, specifically the devices and technical capabilities that are used to implement the procedures attribute. Lastly, the attribute also includes the core system services such as the communication protocols that support and govern operations and interactions.

The final attribute, *data (D)*, focuses on the information or data processed by the system. This deals with both the data format and the content of the information. Data covers a wide range of style and format, but generally it is typed as either homogeneous or heterogeneous. Homogeneous data files are composed of a single content type like a text file. On the other hand, heterogeneous data files consist of multiple forms of information in a single file such as a multimedia document or annotated image. The Architecture Working Group points out that the data attribute is understandably the most critical aspect of attaining systems interoperability. It is within this attribute where much of today's focus and work towards building interoperable systems is taking place. One example of this work is the use of the eXtensible Markup Language (XML), an application-agnostic language used for exchanging information. Due to the scope and time constraints, this area is recommended for a future AFIT Capstone Project.

3.1.3 LISI Reference Model

When all four attributes are measured using the LISI Interoperability Maturity Model the result is a LISI reference model, shown in Figure 5, forms the basis for the assessment of a given system. Systems are graded based upon the level obtained in each of the PAID categories. The overall rating for the system is determined as the lowest of the four category ratings. For example, if a system is rated a level three for procedures, applications and data but a level 1 for infrastructure the overall score is a 1. Each level is

further broken down into three or four sub-levels to distinguish advancement of capabilities.

<i>Computing Environment</i>			P	A	I	D
<i>Description</i>	<i>Environment</i>	<i>Level</i>				
Enterprise	Universal	4	Enterprise Level	Interactive	Multi-Dimensional Topologies	Enterprise Model
Domain	Integrated	3	Domain Level	Groupware	World-wide Networks	Domain Model
Functional	Distributed	2	Program Level	Desktop Automation	Local Networks	Program Model
Connected	Peer-to-Peer	1	Local/Site Level	Standard System Drivers	Simple Connection	Local
Isolated	Manual	0	Access Control	N/A	Independent	Private

Figure 5: LISI Reference Model

3.1.4 LISI and the DoDAF

In developing the LISI model, MITRE specifically related it to the DoDAF as shown in Figure 6. Specifically the model ties to the Operational Views by concentrating on the details of the Information Exchange relationships. It provides a discipline and methodology for discussing and documenting these relationships along with a metric for characterization. LISI expands this by providing information about the set of capabilities the Systems Views use to answer the operational requirements. Lastly, LISI provides an important construct and a bridge to the prevailing formal technical guidance as the link to the Technical Views of the DoDAF.³⁵

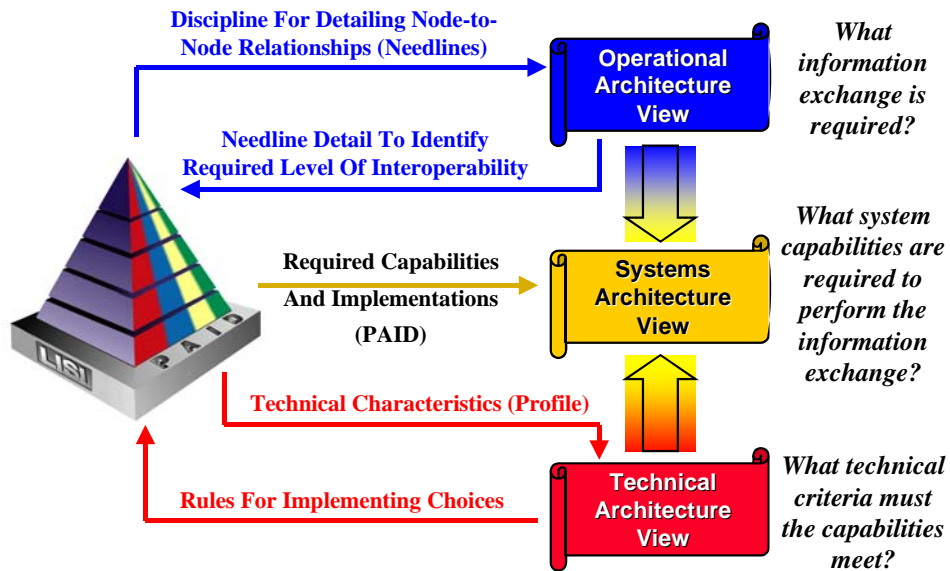


Figure 6: LISI Relationship to the DoDAF Views

3.1.5 LISI Shortcomings

During the research effort a few critics of LISI were discovered, who brought out valid points that should be considered before using this model. The first is a report from Thea Clark, of the Defence Science and Technology Organisation in Canberra, Australia titled *Organisational Interoperability Maturity Model for C2*. The premise for her arguments is that the LISI construct is centered strongly on technology, and more specifically, as its name suggests on information exchanges.³⁶ The construct does not address the higher layers of C2 support and the system-oriented definitions of interoperability levels do not seem to have a natural extension into the higher layers of the model. The report goes on to discuss possible expansion of the LISI model in consideration of interoperability. Of interest is the distinction the report makes between interoperability and compatibility:³⁷

If interoperability is defined as the ability of one entity to service another then compatibility is defined as the degree to which one electronic system can operate with another - it is a subset of interoperability. Thus, when looking at the layers of C2 support, compatibility is more applicable to the lower technological layers and interoperability to the higher organisational layers.

Where interoperability has been driven by process, the focus is on the situation, the people and commander's intent. This may lead to flexible interoperability but not necessarily to technical compatibility: This may be expressed in a logical format as:

Process =>Flexible Interoperability => limited technology compatibility

Where interoperability has been driven by technology, the focus is on assets, their properties and the levels of compatibility required. This may lead to the exclusion of non-compatible participants. In a logical format:

Technology => Planned Interoperability => limited inter-working

This distinction adds credibility to the approach of assessing interoperability of an enterprise level.

Another complaint of the LISI construct is in its difficulty and complexity in implementation. In attempting to find a simple measure to assess interoperability for Joint Forces, Dr. Hamilton from Auburn University along with Major Paul Summers and Captain Jerome Rosen developed this opinion of LISI: "At its core, LISI, is based around classifying levels of interoperability by the 'richness' of communication that a particular system or group of systems allow. We believe the model is, at root, too complicated for use in aggregating the status of the systems at the 'simple' level."³⁸ These sentiments come from the implementation of the LISI construct for interoperability, which is based upon detailed surveys of subject matter experts making it unwieldy for the average program office system engineer to implement.

As an interesting side note to this effort, the Joint Staff has discontinued the required use of LISI in May 2005.

3.1.6 InspeQtor Tool

The research on LISI brought forth the discovery of a tool that MITRE developed for DISA which implements the LISI construct entitled InspeQtor. This web based front-end tool was designed to ease the implementation of the LISI models. The heart of the InspeQtor tool is a survey questionnaire composed of hundreds of detailed questions, which are focused on the information exchanges and technical infrastructure. Users of the tool must first register on the SIPRNET system and then complete the detailed questionnaire by selecting the appropriate response on the survey form. InspeQtor stores and analyzes the answers and generates reports on the systems. These reports are available to describe both the single system and comparisons between multiple systems. Other users are able to log into the tool and look at the survey response for all systems as well as the LISI evaluations. Users are not allowed to modify existing survey responses for systems they do not own.

3.2 *Enterprise Architecture (EA) Score Card*

As an alternate means of assessment to the Levels of Information System Interoperability (LISI) Model, the Enterprise Architecture (EA) Score Card approach was developed by Jaap Schekkerman of the Institute For Enterprise Architecture Developments (IFEAD) in the Netherlands.³⁹ This analysis tool is less comprehensive than the LISI Model and does not depend on interviews with subject matter experts. Surveys of systems can be added to the methodology if desired. The EA Score Card does not exclusively focus on interoperability between systems or architectures. However, this

tool does provide a qualitative measure of EA quality and completeness. A primary benefit is that it can be used on the Architecture products themselves, before a system has been prototyped or constructed. EA Score Card provides a path for improvement in that Systems or Chief Engineers are meant to further develop all aspect areas rated Partially Clear or Unclear until they are rated Clear by later reviews. The results of the EA Score Card analysis are presented in a matrix called the Extended Enterprise Architecture Framework, shown in Table 5.

Table 5: Extended Enterprise Architecture Framework

Aspect Area	Business	Information	Information Systems	Technology Infrastructure
Abstraction Level				
<i>Contextual Level</i>	Business Goals, Drivers and Concepts	Activities the Business Performs	Systems Goals, Drivers and Concepts	Technology Goals, Drivers and Concepts
<i>Environmental Level</i>	Extended Enterprise Value Net	Extended Enterprise Information Exchange	Extended Enterprise Interoperability	Extended Enterprise Interconnection
<i>Conceptual Level</i>	Level of Business Collaboration	Level of Information Interaction	Level of Interoperability	Level of Interconnection
<i>Logical Level</i>	Type of Business Collaboration	Type of Information Interaction	Type of Interoperability	Type of Interconnection
<i>Physical Level</i>	Solutions of Business Collaboration	Solutions of Information Interaction	Solutions for Interoperability	Solutions for Interconnection
<i>Transformational Level</i>	Granularity of Change	Impact of Change	Timeframe for Change	Timeframe for Change

3.2.1 EA Score Card Aspect Areas

The EA Score Card examines four aspect areas of the Enterprise Architecture; Business, Information, Information Systems and Technology Infrastructure. Business represents the organizational and management processes in the architecture. Information measures the information needs, flows and relationships. Information Systems covers the automated processing of functions. Technology Infrastructure corresponds to the logistics and support for the information systems and their connections. The EA Score Card then decomposes these four aspect areas into six abstract levels of concern;

Contextual, Environmental, Conceptual, Logical, Physical, and Transformational, to construct a four-by-six matrix as shown in Table 5. The Contextual level describes the scope and mission of the organization and vision of the architecture. The Environmental level focuses on the extended business relationships and information flows. The Conceptual level explores the functional and non-functional requirements, goals and objectives of the architecture. The Logical level addresses solutions and sub-functions. The Physical layer examines the physical solutions, concrete products and techniques. Finally, the Transformational level measures the payoff in terms of cost, organizational impacts and benefits⁴⁰. The EA Score Card tabulates the sums of each level in an “All Levels” score for each aspect area.

Like the Zachman Framework’s six by five matrix shown in Figure 7, the EA Score Card assesses the Contextual (equivalent to Zachman’s Planning Model) Conceptual, Logical, and Physical levels. However, the Zachman Framework has no cognate to measure costs, organizational benefits and security impacts as does the EA Score Card’s Transformational Level. The Zachman Framework goes further in exploring the architecture in dimensions of Time, People, and Motivation along with Data (Information in the EA Score Card), Function (Business) and Network (Information Systems and Technology Infrastructure).

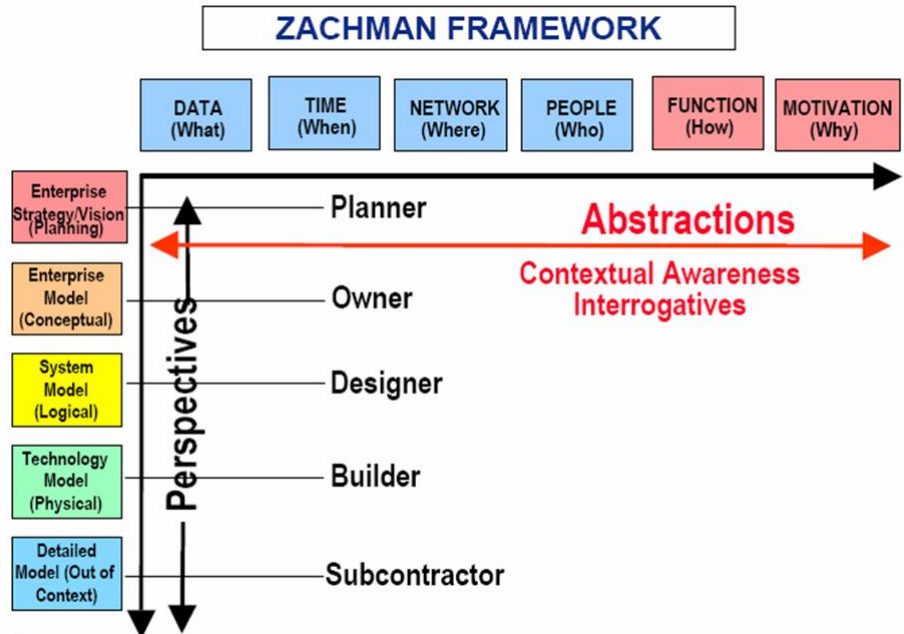


Figure 7: Zachman Framework

The EA Score Card matrix identifies the undefined or nebulous sectors of the architectures as well as thoroughly-documented sections. It can be used to assess whether the architecture fulfills its purpose as well as identify areas for improvement. Further, the EA Score Card assesses integration to report the consistency of architecture documentation products. The EA Score Card measures the architecture products themselves, so it can assess how well the knowledge can be transferred and maintained.

3.2.2 EA Score Card Advantages and Disadvantages

The advantages of the EA Score Card are its visual and intuitive layout, the fact it measures each EA on its own merit, and that it can be applied by Systems Engineering students without proprietary software or access to classified systems. A sample EA Score Card is shown in Figure 8. The primary disadvantage is the tool does not explicitly

measure interoperability between systems. A further disadvantage is non-systems engineers can misinterpret the numerical results. For example, a score of 70% in the Contextual Level does not mean the architecture is “good enough.” The EA Score Card shows strengths and weakness in the architecture, not a stop light bottom-line assessment.

		Enterprise Architecture Score Card							
		Clear = Well defined and documented							
		Partially Clear = partially addressed and documented							
		Unclear = NOT identified or addressed, NOT defined or NOT documented							
	ASC	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Level of Alignment/ Integration	Total Status		
		Business	Information	Information Systems	Technology Infrastructure	Factor 0-2; 0=Insufficient 1=Average 2=Full	2	1	0
1	Are the Mission, Vision, Goals, & Objectives of the Enterprise Architecture?								
2	Is the Scope of the enterprise architecture program?								
3	Is the Form & Function Level of deliverables?								
4	Is the Business & IT Strategy?								
5	Are the Guiding Principles & Drivers?								
6	Are the Key Performance Indicators?								
7	Are the Critical Success Factors?								
8	Are the Critical Stakeholders?								
<i>Sub Score Contextual Level</i>									
9	Are the Collaborative Parties Involved?								
10	Are the Contractual Agreements?								
11	Are the Interoperability standards?								
12	Are the related Law & Regulations?								
13	Is the Ownership of Information?								
<i>Sub Score Environmental Level</i>									
14	Are the Functional Requirements?								
15	Are the Non-Functional Requirements?								
16	Are the concepts in use?								
17	Are the Security Requirements?								
18	Are the Governance Requirements?								
<i>Sub Score Conceptual Level</i>									
19	Are the deliverables at logical level?								
20	Are the critical logical design decisions?								
21	Are the critical logical design decisions traceable?								
22	Are the Logical Description Methods & Techniques?								
23	Is at logical level the use of Modeling Tools?								
24	Are the Logical Standards?								
<i>Sub Score Logical Level</i>									
25	Are the deliverables at physical level?								
26	Are the critical physical design								

	decision?								
27	Are the critical physical design decisions traceable?								
28	Are the Physical Description Methods & Techniques?								
29	Is at the physical level the use of Modeling tools								
30	Are the Physical Standards?								
<i>Sub Score Physical Level</i>									
31	Critical Design Decisions								
32	Is the Organization Impact?								
33	Are the Costs Consequences?								
34	Is the Security Impact?								
35	Is the Governance Impact?								
<i>Sub Score Transformational Level</i>									
<i>Total Score All Levels</i>									

Figure 8: The Enterprise Architecture Score Card Example

3.3 Comparison of LISI and EA Score Card

On the surface, the LISI and EA Score Card models seem to be very comparable approaches. However, this is only true in the separation of EA Score Card aspect areas and LISI Interoperability Attributes. The EA Score Card analyzes Business, Information, Information Systems and Technology Infrastructure while the LISI analyzes Procedures, Applications, Infrastructure and Data. The correlation, as depicted in Figure 9, is not always a one for one representation. Areas such as the LISI Infrastructure and EA Score Card Technology Infrastructure characteristics are virtually identical. This is also true for the LISI Data and EA Score Card Information. On the other hand, some of the EA Score Card Aspect Areas are more of a superset that includes the LISI Attributes. The LISI Application attribute focuses predominantly on software while the EA Score Card Information Systems includes both software and hardware. The LISI Procedures is roughly the same as the EA Score Card Business aspect but LISI focuses more on the management policies and standards driving system integration and requirements determination, where as the EA Score Card Business aspect encompasses on-going organizational functions beyond those necessary for acquisition.

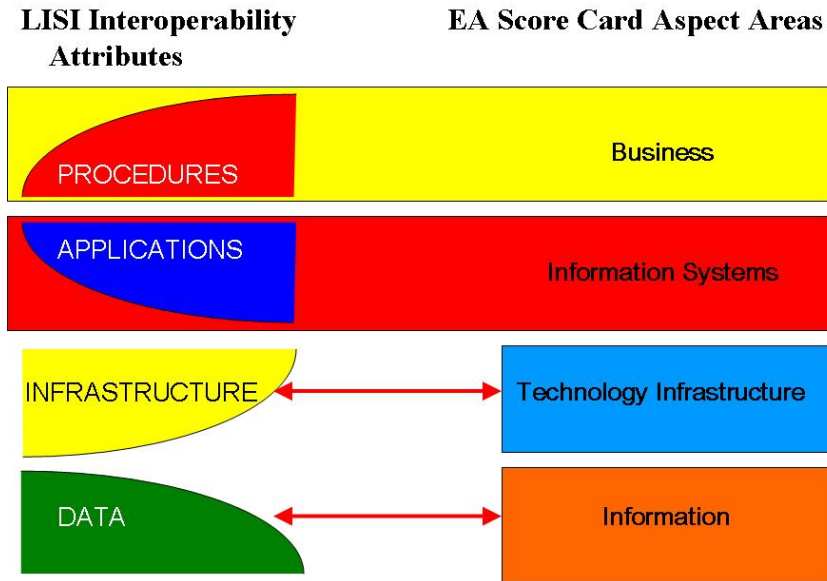


Figure 9: Comparison of LISI Interoperability Attributes and EA Score Card Aspect Areas

The scoring of the two models is very different. The EA Score Card reports on six separate and quantized abstract levels of the architecture. It keeps each output area separate throughout the entire evaluation. For example, a high Business Contextual Level score is independent of the Technology Infrastructure Physical Level results. On the other hand, the LISI model rolls all measurements into a level assessment for each Interoperability Attributes. For example, if a system has a Domain Level 3b score for Procedures but only a Functional Level 2c score for Applications. The LISI model reports a single final score by reporting the lowest score of the four Attributes, a Functional Level 2c.

The biggest difference is the methodology of the two models. The EA Score Card is readily available from the Institute For Enterprise Architecture Developments (IFEAD) web site. A layman can apply the Score Card directly to the architectural products under review. Finally, the EA Score Card is only 35 questions that are answered with respect to

four different aspect areas. By contrast, the LISI model and the InspeQtor tool is only accessible from a Defense Information Systems Agency (DISA) SIPRNET web site, with a separate log-on to the tool. The database questionnaire is hundreds of questions in more than 50 categories. These questions were designed to be answered by the subject matter experts, requiring a level of detail that is much greater than from reviewing the DoDAF products.

The results of both tools need to be closely examined to get a complete picture of the assessment. For example, LISI reports the lowest level as the overall score, so the other areas the system could score much higher. So for both the LISI and EA Score Card tools, the systems engineer must understand the entire context of the results in order to make a useful assessment.

4 Methodology

4.1 EA Score Card Methodology

To analyze the three target architectures, the approach was to answer each of the 35 questions on the EA Score Card applied to each of the aspect areas by reading through the views and material until finding the answers or determining the architects had not considered that aspect of the architecture. When an answer was found in multiple locations and view, the score was increased for that question. Unfortunately, the relative subjectivity of the EA Score Card means each reviewer has to become intimately familiar with the architecture during the analysis process. Additionally, in order to apply consistent scoring only one reviewer scored all three architectures. Multiple analyses by independent reviewers was considered, but due to time constraints this is left for future research.

4.1.1 Assumptions and Constraints

During the EA Score Card Analysis, the following assumptions were made:

1. The students are not the subject matter experts in any of the three enterprise architectures or component systems analyzed (CCIC2S, C2C and GIG). Particularly since they did not participate in the creation or editing of any of the architectures. This is the fundamental direction of the effort and allows for a review by outsiders.
2. Only the architectural material provided was analyzed. This included any Object-Oriented or Structured Analysis created architectural views, diagrams, databases worksheets, white papers, operational requirements documents or briefings included with each architecture. Additional material may have improved the scoring, along with updated versions of the architectures.
3. The rating was marked as “Clear” for any of the 35 analysis questions if a layman could understand the architecture in each aspect area, “Partially Clear” if the question was not fully answered or “Unclear” if the architecture did not address the area of concern. Unclear was also recorded if the architecture was missing the necessary view.
4. In accordance with the EA Score Card methodology, 2 points were awarded for each Clear rating, 1 for each Partially Clear and zero for each Unclear rating.⁴¹
5. EA Score Card questions asking “Governance” concerns were treated synonymously as “management” concerns.
6. The colors used on the EA Score Card are taken from the example included with Schekkerman’s original white paper.

4.2 LISI Methodology and Implementation Issues

The original intent was to apply the LISI model in the same manner as was applied to the EA score card, which looked at the architecture products and answered the survey questions. However, a number of factors conspired to make this not possible. First, access to the InspeQtor tool is controlled by the Defense Information Systems Agency

(DISA) who recently moved the entire tool to the SIPRNET and increased the classification of the tool, data and products to the secret level. This required procurement of both SIPRNET accounts and accounts on the InspeQtor tool. The latter account turned out to be more problematic than anticipated, taking several weeks to gain access. The second factor was the inability to create a separate workspace for inputs outside of the formal tool database. In fact, the standard access privileges on InspeQtor prevent non-system owners from modifying existing surveys on the system and there is not a separate learning area on the tool for users to perform trial runs. A decision was made to instead look at the existing data surveys on LISI for C2C, CCIC2S and GIG and see how it compares to the EA Score Card results to gain an insight on how the two tools compare. However, only CCIC2S survey data was available on the LISI System so the system to system interoperability examination intended with these three architectures was not possible. It was possible to look at how CCIC2S compares to some other systems, outside of the GIG and the C2C, and use that as a basis for understanding how LISI determines system to system interoperability. The final consideration was to attempt to complete the LISI survey based on a review of the architectural products for the CCIC2S. This proved unfeasible due to the detailed nature of the LISI surveys, which are very technical standards and operating system specific. Further, these surveys are not compatible with the level of detail in the architectures. For example, the LISI tool has 63 separate questions concerning the applicable security standards for the system. In other words, the enterprise architectures were at a higher level (enterprise) while the intent of LISI is to examine systems at the detailed system interface level. After discussing the

prospects of completing a survey, it was determined to exceed the time and scope of this project.

5 Results of Analysis

5.1 EA Score Card Analysis

The results of the analysis of the three architectures using the EA Score Cards are presented. This analysis was completed in April - May 2005. The EA Score Card model simply presents the raw numbers as a final product. The raw data sheets from the analysis can be found in Appendix A. In order to succinctly present the results, tabulated the totals for each aspect area and level are shown along with graphical bar charts to compare levels and spot trends. Graphic representation of results is provided using the same scale height, with the highest percentage being the baseline, to minimize misinterpretation.

To ensure comparison of only like characteristics, each architecture was measured for a consistency across the six abstract levels plus the all levels score. To develop this consistency, a standard deviation of the level scores was used to show the degree of completeness for each architecture. Consistency is defined as a less than 10% range among aspect area scores for the same level of concern. The limitation of this yardstick is each architecture must be compared to the stated purpose for creating it in the first place.

5.1.1 C2C EA Score Card Analysis

Table 6: C2C Results

	Business	Information	Information Systems	Technology Infrastructure
<i>Contextual Level</i>	44%	44%	50%	50%
<i>Environmental Level</i>	70%	80%	70%	70%
<i>Conceptual Level</i>	70%	60%	60%	60%
<i>Logical Level</i>	50%	42%	42%	42%
<i>Physical Level</i>	8%	17%	17%	17%
<i>Transformational Level</i>	50%	10%	10%	20%
<i>All Levels</i>	47%	42%	42%	43%
<i>Standard Deviation</i>	.74	.90	.87	.82

Table 7: C2C Predominate Views Used in Score Card Analysis

<i>Contextual Level</i>	AV-1 Overview and Summary Information OV-1 High Level Operational Concept Graphic OV-3 Operational Information Exchange Matrix OV-6a Operational Rules Model
<i>Environmental Level</i>	AV-2 Integrated Dictionary OV-3 Operational Information Exchange Matrix OV-5 Operational Activity Model OV-6a Operational Rules Model SV-4 Systems Functionality Description
<i>Conceptual Level</i>	OV-3 Operational Information Exchange Matrix OV-5 Operational Activity Model OV-6a Operational Rules Model SV-4 Systems Functionality Description
<i>Logical Level</i>	AV-1 Overview and Summary Information OV-5 Operational Activity Model SV-5 Operational Activity to Systems Function Matrix TV-2 Technical Standards Forecast
<i>Physical Level</i>	SV-4 Systems Functionality Description TV-2 Technical Standards Forecast
<i>Transformational Level</i>	AV-1 Overview and Summary Information SV-9 Systems Technology Forecast

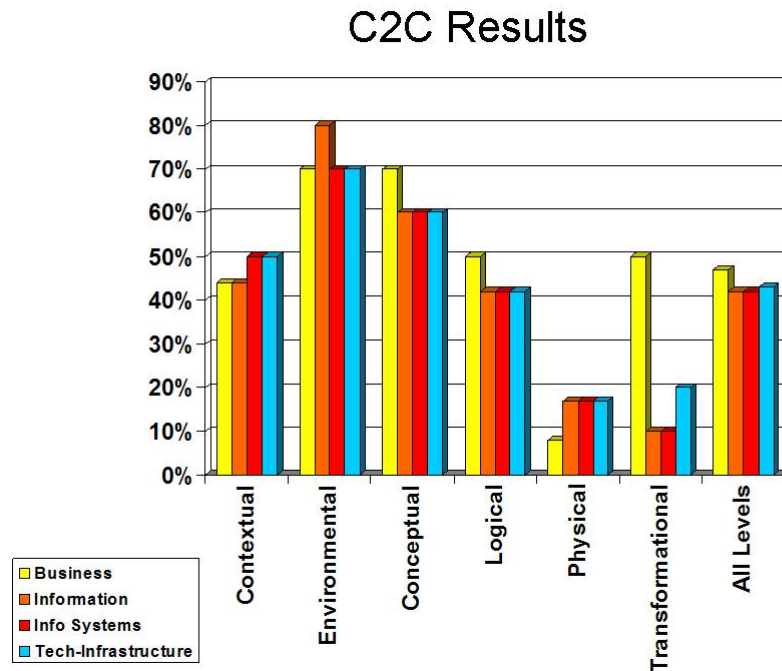


Figure 10: C2C Score Card Results

The C2C analysis required the most time and energy due to a lack of a webpage browser or central directory to guide us through the architecture. Further, the C2C Overview briefing from December 2003 raised the question of whether an architecture completed at the Unclassified level contained sufficient detail or thoroughness to warrant the effort to complete it. A cohesive assessment of the C2C Architecture did not come into focus until the data, in Table 6, was graphically displayed as shown in Figure 10.

The C2C Architecture rated the highest scores, meaning it was most fully documented, at the Environmental and Conceptual levels, due to its 2005 “As-Is” and 2012 “To-Be” views. A complete listing of the architectural products used in the analysis is in Table 7. Specifically, the architects created detailed OV-5 Operational Activity Models and OV-6a Operational Rules Models for both 2005 and 2012 timeframes as well

as stand-alone, focused models to support the Time Critical Targeting concept and its evolutionary successor Time Sensitive Effective Operations.

All four aspect areas were consistent for each level of concern, save one. Using the definition of consistency as less than a 10% range among aspect area scores for the same level of concern, there was a great disparity between the Business Aspect Area (50%) and the other three areas (10% - 20%) in the C2C Transformational Level. This is due to relatively clear depictions of decision processes, milestones, organizational impacts and costs for the C2C Business processes in the AV-1 Overview and Summary, C2C Overview Briefing and Program Plan Documents. The Information, Information Systems (IS) and Technology Infrastructure (TI) impacts were merely mentioned in one slide of the C2C Overview Briefing or not at all.

Typical to all three architectures, the Physical Level scored the lowest, showing the lack of views prepared for physical systems. This may be a necessary by-product of investigating big-picture enterprise architectures which become too ponderous to keep current if they explicitly define the physical levels of the systems which reside within their macro-level system.

Based on the EA Score Card analysis, the C2C Architecture *partially* met its many purposes. The Architecture does a commendable job of supporting C2C definition, conceptual design, requirements development, early milestone decision reviews and concept of operation maturation as shown by strong Environmental and Conceptual Level scores. Its Contextual and Logical levels scores seem adequate to facilitate Global Information Grid architecture compliance. The C2C architecture infers Integration Points with the GIG Architecture by mentioning GIG compliance as an objective in one of the

many briefings included with the architecture, however it does not graphically illustrate any Integration Points anywhere in the architecture.

However, for an architecture created to prototype a Joint Mission Thread and Air Force Mission Area, one might expect higher Transformational Level and All Level Scores. Also, one would hope for stronger architectural views that rely less on supporting briefing material to avoid the perception of “architecting by Power Point.” This weakness can be explained by the fact the C2C version 2.0 is a draft architecture⁴² and the next revision, expected late 2005, should be more robust.

5.1.2 CCIC2S EA Score Card Analysis

Table 8: CCIC2S Results

	Business	Information	Information Systems	Technology Infrastructure
<i>Contextual Level</i>	50%	89%	89%	67%
<i>Environmental Level</i>	40%	60%	50%	70%
<i>Conceptual Level</i>	50%	70%	80%	60%
<i>Logical Level</i>	25%	58%	33%	33%
<i>Physical Level</i>	0%	8%	8%	0%
<i>Transformational Level</i>	20%	10%	10%	10%
<i>All Levels</i>	32%	53%	49%	42%
<i>Standard Deviation</i>	.75	.94	.93	.87

Table 9: CCIC2S Predominate Views Used in Score Card Analysis

<i>Contextual Level</i>	OV-4 Operational Command Relationships OV-5 Operational Use Cases
<i>Environmental Level</i>	Operational Requirements Document
<i>Conceptual Level</i>	Operational Requirements Document
<i>Logical Level</i>	OV-5 Activity Diagrams
<i>Physical Level</i>	Operational Requirements Document
<i>Transformational Level</i>	White Paper

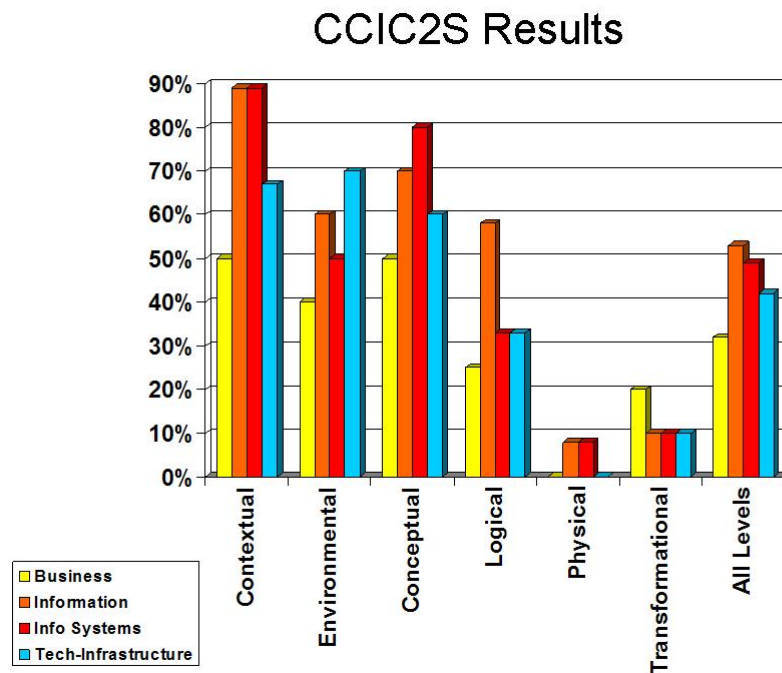


Figure 11: CCIC2S Score Card Results

Unlike the other two enterprise architectures examined, the AFSPC systems engineers, architects, and requirements analysts used an object-oriented approach, commonly used by software engineers, to rapidly update the evolving missions of the CCIC2S architecture. Initially a Structured Analysis approach was tried, but it was abandoned as it could not keep pace with the mission evolution.⁴³ They created an operational architecture heavily focused on the Information and Information Systems (IS) Aspect Areas.

The raw data is presented in Table 8, with the graphical representation in Figure 11. Consistency varied the most among the CCIC2S aspect areas. By using the Consistency definition of a 10% or less variance in the range of scores, only the Physical and Transformational Levels are consistent for the CCIC2S Architecture. They are consistently low, however, averaging roughly 10%. They highlight a general lack of

deliverables, modeling tools, impacts and cost development for the architecture. Physical concerns are not addressed at all for the Business and Technology Infrastructure aspect areas. This is reflected in the All Levels scores. The lower scores in the Logical and Physical Levels is also attributable to the fact the CCIC2S operational architecture contains no Systems Views. This is concerning since CCIC2S was characterized as more 'system-like' than 'enterprise.' However, it is necessary to recall the purpose for which the architecture is built. CCIC2S is an operational architecture put together by an operational command for the purpose of capturing user requirements leading to a detailed design, so one would not expect to find many Systems Views. A complete list of the products used in this assessment is found in Table 9.

Information and IS scores are higher than Business and Technology Infrastructure (TI) across most levels of concern. This is due to the deeply-comprehensive OV-5 Use Cases which present a vast range of operational functions, and then cross-references them to the resulting Operational Requirements Document (ORD). The Contextual Information and IS scores are the highest in the entire analysis at 89% each, signifying the architecture is most fully developed for the enterprise mission, drivers, vision and scope. This also is reflected in the All Levels Scores as well.

The CCIC2S Architecture met its purpose, because it's primary function was to capture user and operator requirements for detailed design and test of the CCIC2S system. However, additional systems functions need to be identified before testing can begin. The operational architecture needed to integrate common functions across many different legacy systems developed in stovepipe manner. The resulting architecture contains the deepest levels of operational functional details for the ORD of all three

architectures analyzed. However, the object-oriented approach resulted in complex use cases that relied upon the ORD for navigation and indexing. Only systems engineers familiar with both Structured Analysis and object-oriented approaches will feel comfortable reading such difficult diagrams. Systems views should be developed for the architecture to capture a complete view of the proposed capability. Integration Points are not identified to show commonality with other architectures, although GIG interfaces are mentioned briefly at the beginning of the Operational Requirements Documents (ORD).

5.1.3 GIG EA Score Card Analysis

Table 10 GIG Results

	Business	Information	Information Systems	Technology Infrastructure
<i>Contextual Level</i>	72%	72%	67%	56%
<i>Environmental Level</i>	50%	50%	60%	40%
<i>Conceptual Level</i>	70%	80%	80%	60%
<i>Logical Level</i>	75%	67%	75%	75%
<i>Physical Level</i>	25%	42%	50%	50%
<i>Transformational Level</i>	60%	60%	60%	60%
<i>All Levels</i>	60%	63%	65%	57%
<i>Standard Deviation</i>	.68	.70	.71	.70

Table 11 GIG Predominate Views Used in Score Card Analysis

	OV-1 High Level Operational Concept Graphic OV-2 Operational Node Connectivity OV-4 Command Relationships SV-1 Systems Interface SV-2 Systems Communications
<i>Contextual Level</i>	
<i>Environmental Level</i>	Program Management Plan
<i>Conceptual Level</i>	AV-1 Overview and Summary Information
	OV-3 Operational Information Exchange Requirements OV-5 Activity Model SV-1 Systems Interface SV-2 Systems Communications SV-3 System Matrix SV-4 System to System Functions
<i>Logical Level</i>	
<i>Physical Level</i>	TV-2 Technical Standards Forecast
	Program Management Plan Capstone Requirements Document
<i>Transformational Level</i>	

GIG Results

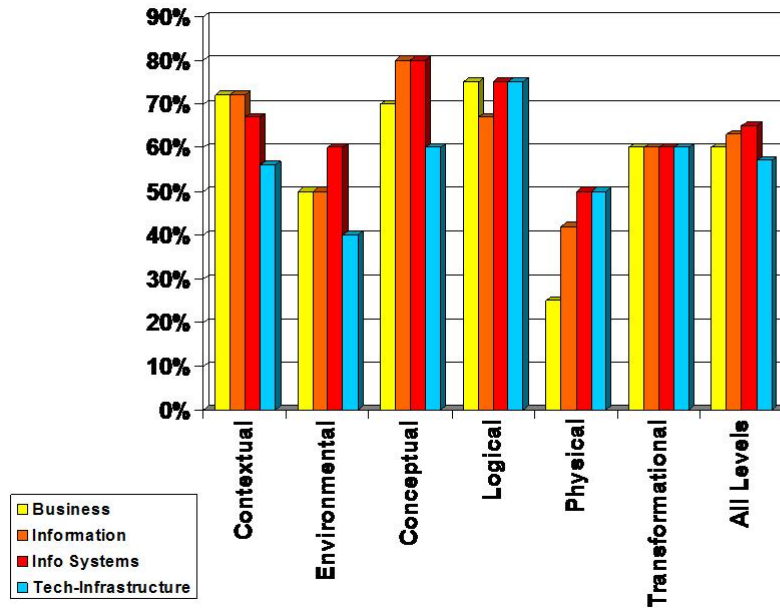


Figure 12: GIG Score Card Results

The HTML browser developed for the GIG v2 Architecture was both the easiest to use layout and contained the most clearly labeled architectural products. The GIG scores,

shown in Table 10 and graphically in Figure 12, are both the highest and most consistent both within aspect areas and across levels of concern. This is easily explained by the nearly complete sets of architectural views, listed in Table 11, developed for the three Strategic, Operational and Tactical Use Case scenarios. As with the other two architectures, the Physical Level has the lowest scores, representing the least amount of documentation. However, the GIGs Physical Level scores were comparable to the more developed levels of the other two architectures. The GIG v2 Architecture does not need well developed Physical Level models to facilitate Chief of Information Operations (CIO) planning and acquisition decisions.

The Conceptual, Logical and Contextual Levels scored the highest percentages; showing well-developed missions, vision, requirements, logical solutions and scope of the EA. The Transformational and Environmental Levels were slightly lower but still above the comparable levels of the other two architecture. The Transformational Levels was completely consistent across aspect areas (all four scored 60%). This shows the developers efforts to make the operational, systems and technical views equally strong. It also ties back to the architecture's purpose to serve as a NCW model. Additional views to support the Transformational Level will only improve the GIG architecture.

The GIG v2 architecture meets its purpose, providing the initial architectural description of NCOW concepts, terminology and modeling. The vast scope of the GIG makes defining the Environmental and Physical Levels nearly impossible. The use of the Strategic, Operational and Tactical Use Cases makes the crisp architectural views able to present the knowledge without having to rely on extensive briefing material, operational requirements documents or white papers. Integration Points for the GIG v2 Architecture

are defined with national-level strategic decision makers as nodes on the OV-1 High Level Operational Graphic. Integration Points with other specific Enterprise Architecture are not explicitly defined. Additional architectural views would definitely improve the scores of the GIG architecture. However, one can imagine the expensive cost of maintaining this easy to use, standardized document. The current number of views may be the optimal for effective updates to the GIG architecture.

5.2 LISI Analysis

The results of the analysis of the CCIC2S Architecture using the LISI model and InspeQtor front end tool was conducted in May of 2005. Much of the data and comparisons remain classified, so discussion of results in this forum is limited. The surveys require inputs from those knowledgeable in the system and not designed for the intended aim of conducting an assessment from only the architecture product. For example, one series of questions in the survey asks about the operating systems being used, such as Linux, Sun Solaris or Microsoft Windows and the associated patches in place.

However, the actual charts and comparison features of the tool were intuitive to use, quickly learned and easy to navigate using only a standard internet browser. In looking at one product for examining interoperability with other systems, the tool displayed an Interconnectivity Report in matrix form. While this seems logical, further research revealed there was no scientific rationale or logical connections, but rather the Subject Matter Experts claiming connections to other systems. It did provide the ability to see if the systems experts claimed interconnectivity and, more importantly, if the systems experts from both systems agreed on the interconnectivity.

6 Results of System to System Analysis

6.1 EA Score Card Comparisons

While the EA Score Card model is successful at identifying the holes, areas of concern and strong points of individual enterprise architecture, it does not suggest ways to compare architectures against each other. Neither does it attempt to develop criteria for defining when architectures are comparable to each other. Investigation of the three architectures revealed that while the CCIC2S and C2C Architectures both refer to the GIG Architecture in general terms, the GIG v2 naturally does not mention either of the others. The GIG v2 scenarios do not include application of the other architectures and it was not possible to develop a common scenario due to a lack of mission commonality between the CCIC2S and C2C. The C2C is designed for major theater war operations while the CCIC2S focuses specifically on AFSPC, STRATCOM and NORAD space missions. However, it is possible to do a comparison at the individual levels of concern: contextual, environmental, conceptual, logical, physical, transformational and all levels; as a measure of interoperability.

Comparison of Contextual Level

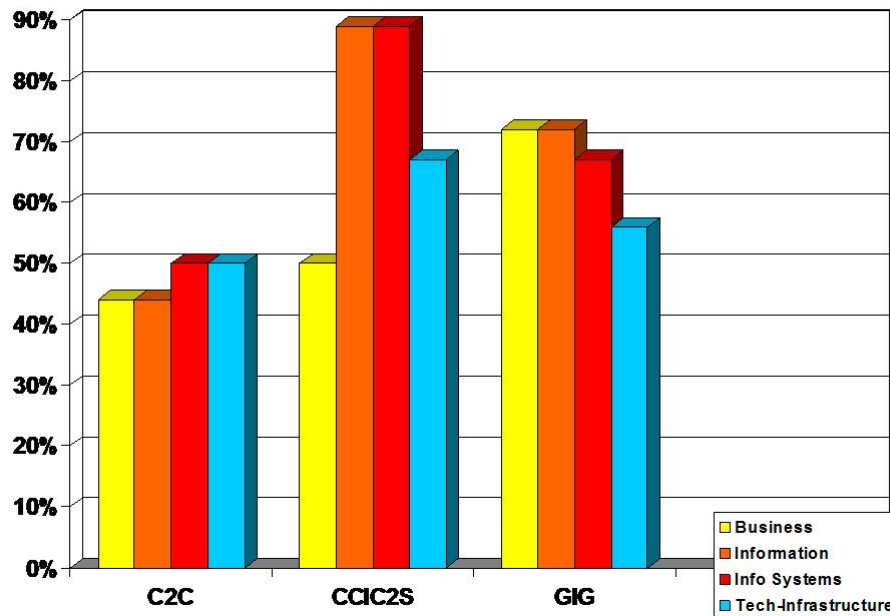


Figure 13: Comparison of Contextual Levels

As previously stated during the CCIC2S results, it showed the highest scores for the Contextual Level, especially for the Information and Information Systems aspect areas. This spike is not reflected in the CCIC2S All Levels results. This demonstrates the pitfall of attempting to reduce the EA Score Card to a simple average of all levels and aspect areas. The EA Score Card model is too complex to reduce to a simple average score. The CCIC2S operational architecture was created to support an Operational Requirements Document and its low scores in other levels does not prevent it from accomplishing its fundamental mission. The percentages for the three architectures at the Contextual Level, as shown in Figure 13, reflect the separate uses each was created to serve.

Comparison of Environmental Levels

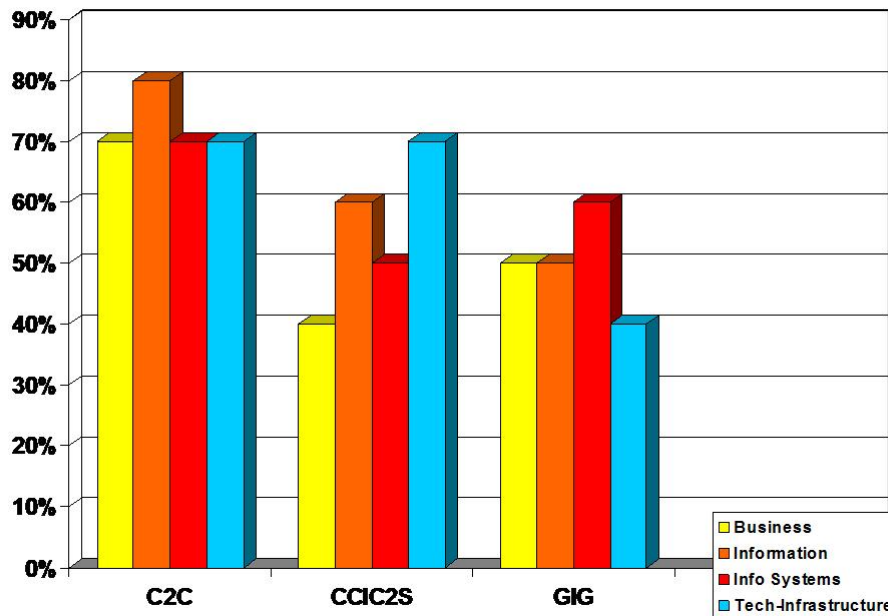


Figure 14: Comparison of Environmental Levels

The data, in Figure 14, shows the C2C has higher scores on the Environmental Level due to stronger documentation of interoperability standards, laws and regulations and information ownership definitions. The C2C Architecture is not only stronger at the Environmental Level but more consistent as well.

While the Environmental Level contains the bulk of interoperability questions, it cannot alone answer the question of how interoperable the architectures are. The nature of the architectures mission must be considered in order to answer how interoperable the architecture is as a result. While both the CCIC2S and C2C architectures define their interfaces with the GIG, the reverse is not true.

Further, the CCIC2S and C2C architectures do not directly interface due to a lack of common mission areas. This makes direct comparison significantly more difficult since it is not practical to develop a common scenario to demonstrate the interoperability of

integration points across the enterprise architectures. Careful selection of architectures and their external system boundaries must be undertaken in order to use scenario development to illustrate interoperability. This effort should be the basis for another group research project.

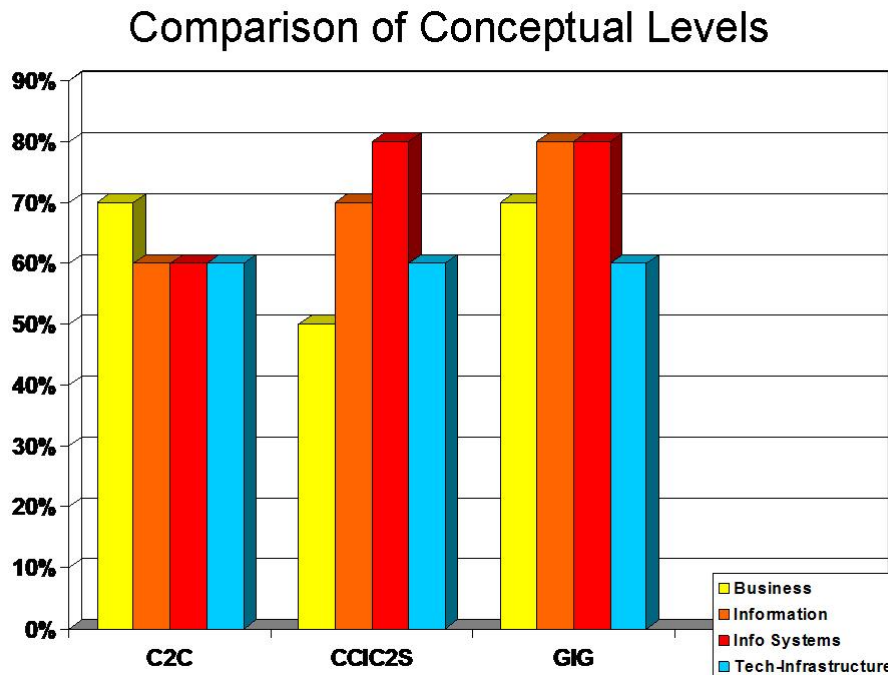


Figure 15: Comparison of Conceptual Levels

Figure 15 displays the Conceptual Level comparison where the three architectures show approximately equivalent scores due to a roughly equal focus on Security, Governance, Functional and Non-Functional Requirements. The definition of requirements is a common objective to all three architectures and is very well-documented in both the CCIC2S and C2C architectures. The structured analysis approach used in the GIG and C2C architectures led to OV-5 Activity Model views that more clearly showed the functional requirements when compared to the CCIC2S object-

oriented UML produced OV-5 Activity Diagram and Use Cases. The CCIC2S architects balanced this with a clearly defined requirements matrix in the ORD.

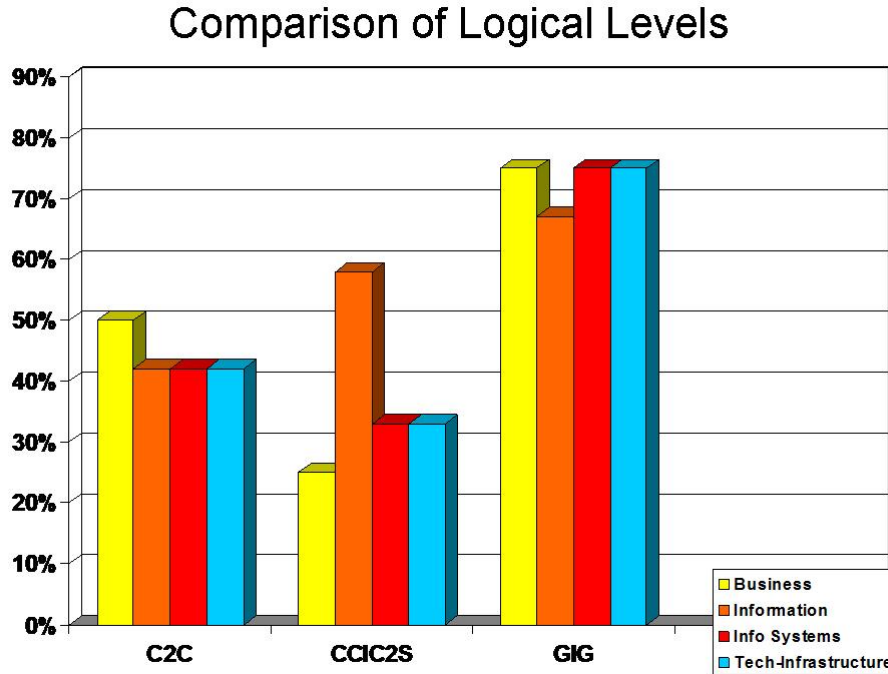


Figure 16: Comparison of Logical Levels

At the Logical Level, depicted in Figure 16, the GIG architecture is clearly more well-developed and consistent. This is due to the clear and extensive Systems View Diagrams that expand on the operational views functions and nodes and define the system entities that make up a real system of system. It is also the first level that demonstrates the all-around strength of the GIG v2 Architecture. By comparison, the Object Orientated Approach based CCIC2S architecture contained only one systems view. The C2C system views only supported their operational views and did not include an SV-1 Systems Interface or SV-2 Systems Communication view.

Comparison of Physical Levels

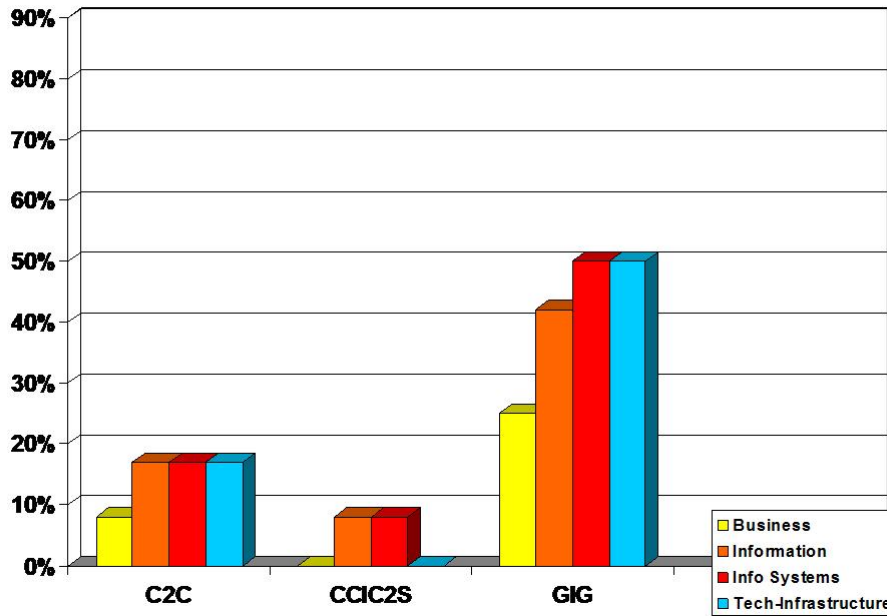


Figure 17: Comparison of Physical Levels

While the Physical Levels, graphed in Figure 17, do represent the least developed level of concern amongst the three subject enterprise architectures, the GIG v2 shows an order of magnitude difference relative to C2C and CCIC2S. While the GIG Architecture is weakest at the Physical Level, it is at least Partially Clear in many areas the other two architectures do not even mention. This is the second level of concern that shows the all-around strength of the GIG Architecture. Ultimately, weak physical levels are expected when reviewing Enterprise Architectures due to their concern with the broad scope and vision of the subject organization. Despite the expected low scores, it is important to assess the physical aspects of the Enterprise Architecture to provide systems engineers with a complete understanding of their architecture.

Comparison of Transformational Levels

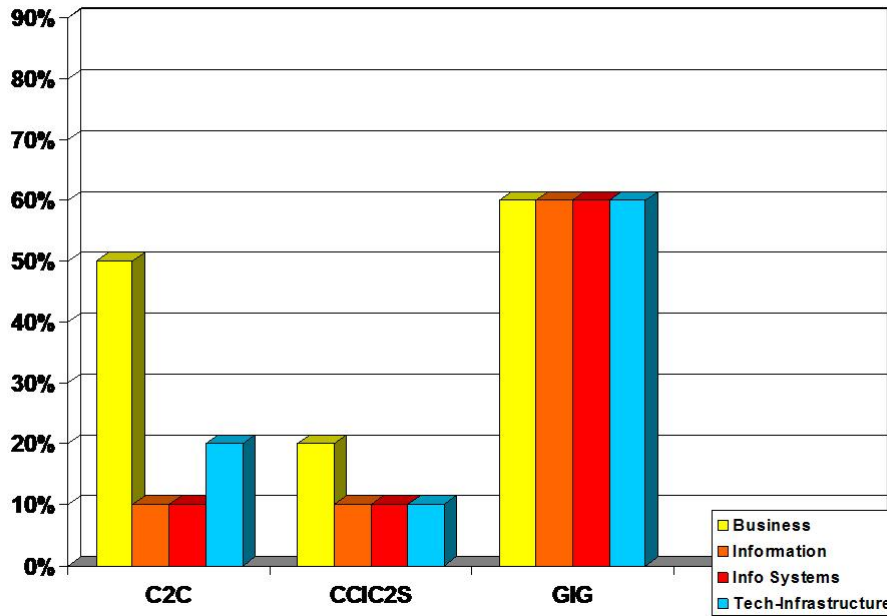


Figure 18: Comparison of Transformational Levels

The Transformational Levels of Figure 18, like the Physical Levels of Figure 17, shows an order of magnitude difference between the GIG Architecture and the CCIC2S and C2C. Only the Business Aspect Area of the C2C is comparable, due mainly to a definition of cost and organizational impacts in the C2C Overview briefing. Risk analysis, cost, organizational, management and security impacts are the prime determiners of Transformational Level scores. In these three cases, Structured Analysis and Object Orientated approaches do not address the transformational impacts in architectural views. This is not a fault of either approach, but rather of the detail and purpose of the individual architectures. Transformational Level information was detailed in supplemental text documents such as white papers, management plans or the CCIC2S ORD.

Comparison of All Levels

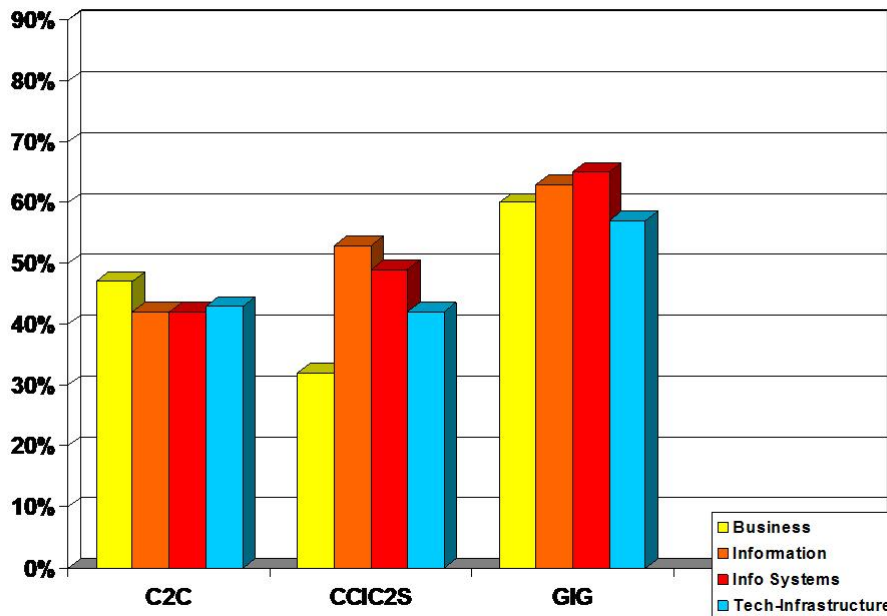


Figure 19: Comparison of All Levels

Unfortunately direct comparison of the All Levels scores in Figure 19 only suggests the all-around strength of the GIG v2 Architecture and masks the successful portions of all three architectures. This argues strongly against using the All Scores percentages as a “Traffic Light” chart to show architecture merit in overly quick terms of Green/Yellow/Red. In fact, Systems Engineers would profit from NOT publishing the Score Cards themselves and presenting the strong, weak and missing parts of their architectures in text form to policy and decision makers. The Score Card model requires an in depth understanding of both the architecture and the model methodology to appreciate the raw data. There is a risk non-Systems Engineers could misinterpret the All-Levels scores as being “good enough for government work” without realizing their architecture fails to serve one of its fundamental purposes because the numerical score masks the omission. However, the Score Cards do serve a valuable purpose to Systems

Engineers in helping complete the architecture and this merit makes it worthwhile to complete the analysis.

6.1.1 Conclusions

From the percentages charted above, one can see the relative comparisons. The GIG Architecture scored highest across all four aspect areas and the six levels of concern. From this analysis, one infers the GIG architecture is the most complete and contains the deepest levels of detail. However, as discussed in the individual results sections, all three architectures have strengths and weaknesses that affect performance at their intended uses.

The purpose and intended use of the enterprise architecture is still paramount in measuring its effectiveness. The All Levels results suggest the C2C and CCIC2S are roughly comparable to each other in effectiveness and completeness, however, the CCIC2S architecture was only intended to support an Operational Requirements Document, a goal it clearly achieved by careful examination of the Score Card numbers and the Contextual and Conceptual Level results. The C2C Architecture is described by its AV-1 Overview as a “Sub-Enterprise Level” architecture to define the highest-level aspects of the C2 Constellation but does not include all of the functionalities and associated systems. Future phases of the architecture will provide further depth and extend the scope.

Finally, the EA Score Card model, while useful for assessing the completion and maintainability of an enterprise architecture, does not sufficiently answer the goal of defining interoperability among architectures. More detailed analysis and modeling is

required to answer this question. In fact, the lack of a readily useful tool to measure interoperability suggests applied research should be undertaken to develop one.

6.2 *LISI Results and Conclusions*

Looking at the specific data available for CCIC2S, brings forth similar results to the analysis from the EA Score Card when looking at only the single architecture. The attributes of procedures and data rated high while the application and infrastructure was lower. This is to be expected, and verifies the EA Score Card results, as the CCIC2S architecture was designed to produce an Operational Requirements document and is lacking many of the systems views associated with a physical architecture

6.3 *Findings*

After having looked at the Enterprise Architectures this past year and specifically as part of this capstone project looking at interoperability, lead to arrival upon four key findings. First and foremost, when evaluating an architecture, the decision maker needs to be aware of the intended purpose for which the architecture was built. This purpose will heavily influence what architectural views are developed and the depth of detail in those views.

Second, not all architectures are the same. For example, two of the architectures examined were intended for more of an enterprise/concept definition use (C2 and GIG), thus did not contain as much system specific information. CCIC2S, on the other hand, is a little lower level and has much more of a system feel. In addition, because of the interactive nature of architectures the maturity of the architecture needs to be kept in mind when examining for details.

The third finding is the lack of a single tool to measure interoperability based solely on architectures documents. The Enterprise Architecture Score Card is a good common reference point for systems engineers to start examining single architectures. During the capstone project of examining interoperability, it was found that the EA Score Card is better suited for evaluating architectures in relation to intended purpose and helping to identify possible gaps in the architecture. LISI, on the other hand, is better suited for identifying interoperability issues, but is extremely difficult to use. To get the complete picture, both tools should be utilized as part of a GAP analysis in the JCIDS process, or another tool should be developed.

Lastly, correctly created architectures can help the JCIDS and PPBE processes for making investment decisions, but because so many architectures are incomplete and created with different purposes it is possible to understand why decision makers may not be realizing the perceived benefits. The DoD did attempt to include this information as a part of its Net-Centric Program Assessment. However, the series of 68 questions that were a part of the survey were extremely broad in nature. For example, the survey asked about the use of architectures via conformance to the DoDAF and if the various views were updated. However, it did not go into any analysis of the architectures or integration between systems. While this assessment doesn't measure interoperability like LISI or the EA Score Card, it does attempt to re-enforce conformance to net-centric services and provides a use of architectures in the budgeting process.

The bottom line is current enterprise architectures assessment tools have not kept pace with the relevant key performance parameters (KPP). Over the past, the LISI Model was designed to perform the Interoperability assessment, as shown in Figure 20.

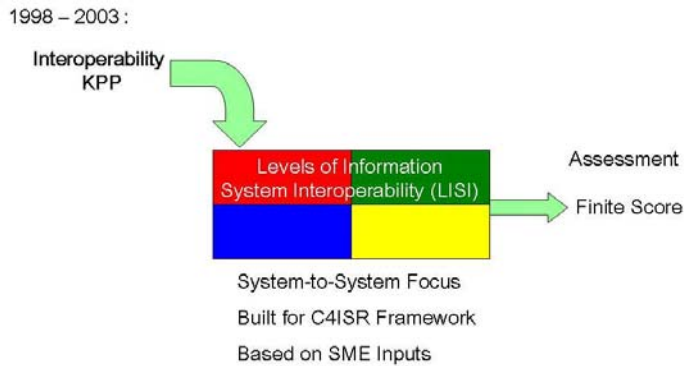


Figure 20: Past Interoperability Assessment Methodology

However, Network Readiness is now the dominant KPP with interoperability just a factor in the NR-KPP equation. Likewise the assessment tools and methodology for enterprise architecture assessment models need to adapt. Currently, there is not a single tool to assess the quality of net-centricity in a system, as shown in Figure 21.

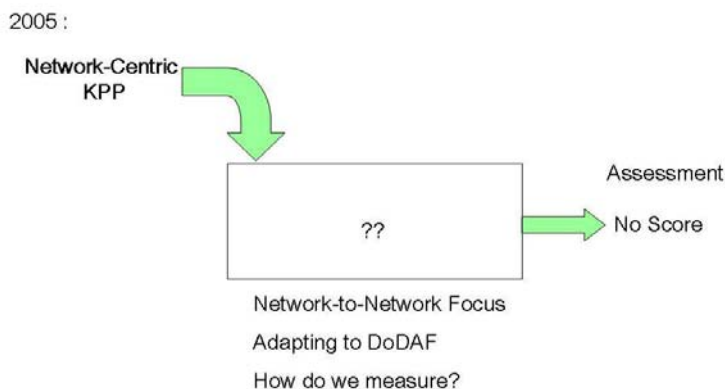


Figure 21: Today's Net-Centric Assessment Methodology

The focus of measuring interoperability may no longer be the question, but rather how a measurement of network centricity or network readiness compared to the GIG standard as depicted in Figure 22.

2007 :

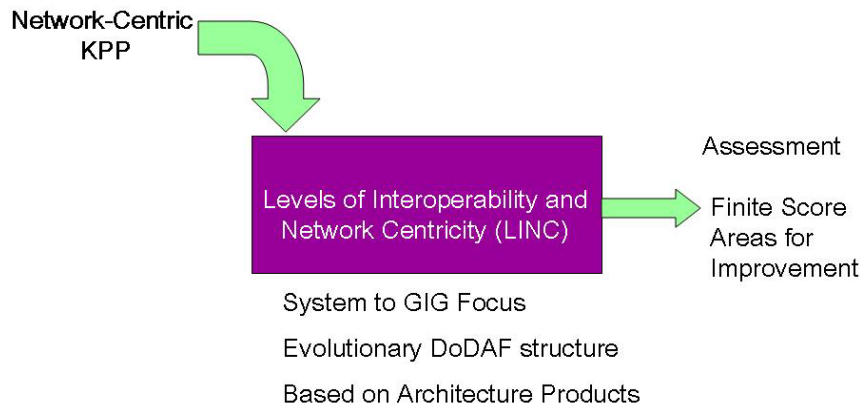


Figure 22: Proposed Net-Centric Interoperability Methodology

Completing the EA Score Card for a few architectures provides the ability to start predicting EA Score Card scores based on the stated purpose and available architectural views. This still does not accomplish the goal of measuring system to system interoperability, so additional research is necessary to develop an assessment tool that can measure not only interoperability, but more specifically the Network Centricity of systems connecting to the GIG.

6.4 Recommendations for Further Study

During the course of this project, several additional areas of interest were identified, where further study could be of value to decision-makers, system engineers, and architecture communities.

6.4.1 New Tool for Measuring Interoperability

The lack of a readily applicable tool for measuring interoperability between architectures, as well as a stand-alone assessment, suggests additional research and the creation of new tools. Two candidate system architectures that could be used as control

cases during tool development are the CCIC2S and the Rapid Attack Identification Detection Reporting System (RAIDRS). Both of these systems have completed LISI evaluations and the data is readily available on InSpeQtor which can be used to validate development. The task is to develop a tool that measures the net-centricity of systems in relation to the GIG standards while evaluating not just interoperability but compatibility of systems.

6.4.2 The Role of eXtensible Mark-up Language (XML) in Architecture Documents

During the course of this research, possible investigation into the belief that one could measure commonality and interoperability in architectures by looking at the data models of the architecture. One possible solution to assure interoperability of the data models is to use a common language like XML to format the metadata in the data dictionary and data models. The Department of Defense has created an XML registry to ensure interoperability. During the Net-Centric Program Assessment, programs were asked about their use of metadata and conformance to the DoD Discovery Metadata Specification along with registration in the registry. This registry provides a baseline set of XML Information Resources developed through coordination and approval among the DoD communities. This registry can be found on the World Wide Web at <http://diides.ncr.disa.mil/xmlreg/user/index.cfm>. It would prove beneficial in using XML to develop the data dictionary in architectures and provide for interoperability.

6.4.3 Determining the Right Number of Architecture Views

While the DoDAF directs a specified set of views to have a complete architecture, during the course of this project, investigation found that a set number or type of views is not an indication of completeness. Sometimes it is possible to have all of the information

needed for the purpose on a subset of the required charts, while other times more detail is required. Recently, the DoDAF version 2 was released and attempts to start addressing this issue with overlays. One possible research topic for further study is to analyze the existing products and capture the required information to be present for the various milestone decisions.

6.4.4 Comparing Architecture Design Methodology – Object Orientated versus Structured Analysis

In reviewing the three architectures, it is interesting to note that two were built with the traditional Structured Analysis (SA) approach of systems engineering that centers on functional allocation. The third architecture, CCIC2S, was built using an object orientated (OO) approach based on a software development model. The two approaches are both covered in the DoDAF, but which way is better or more able to produce a complete architecture is open for future research. A potential sponsor for a project like this is AFSPC/DRF as they posed similar topics during discussions with them.

6.4.5 Sensitivity analysis for EA Score Card Results

One critique of the assessment methods was having a single individual perform the EA Score Card assessment. While all members participated in the analysis of results, it was decided early on to have a single person generate the scores to ensure each architecture so the scored was based on similar interpretations of the tool. The conducting of the score generation by multiple users may provide some insights. The manpower to generate the EA Score Card assessment data consumed about 120 man hours for the 3 Enterprise Architectures.

7 Bibliography

Air Force Inspection Agency. *Architecture-Based Acquisition (ABA) EAGLE LOOK*. Kirtland Air Force Base, NM: Headquarters Air Force Inspection Agency, October 2003.

Brown, David P. *Enterprise Architecture for DoD Acquisitions*. Acquisition Review Quarterly. Fort Belvoir, VA: DAU Press, Spring 2000.

Buede, Dennis M. *The Engineering Design of Systems Models and Methods*. New York: John Wiley & Sons, Inc., 2000.

C2C Overview and Summary Information (AV-1), Version 2.0, 21 November 2003.

C4ISR Architecture Working Group, *Levels of Information Systems Interoperability*, 30 Mar 1998.

CCIC2S Operational Architecture User's Guide, 15 March 2004.

Chairman Joint Chiefs of Staff (CJCS). *Joint Capabilities Integration and Development System Instruction. CJCSI 3170.01C*. Washington: Joint Chiefs of Staff, 24 June 2003.

Chairman Joint Chiefs of Staff (CJCS). *Joint Capabilities Integration and Development System Manual. CJCSM 3170.01A*. Washington: Joint Chiefs of Staff, 12 March 2004.

Chairman Joint Chiefs of Staff (CJCS). *Interoperability and Support of Information Technology and National Security Systems. CJCSI 6212.01C* Washington: Joint Chiefs of Staff, 20 November 2003.

Clark, Thea; Organisational Interoperability Maturity Model for C2, Defence Science and Technology Organisation C3 Research Centre, Fern Hill Park, no date.

Colombi, John. *System Engineering and System Architecture*. Power Point presentation provided to researcher by author, no date.

Cooper, Cecily D. *Not Just a Numbers Thing: Tactics for Improving Reliability and Validity in Qualitative Research*. Los Angeles, CA: University of Southern California Marshall School of Business, no date.

Dam, S. and Long, James E. "Developing Executable Architectures for Systems of Systems (SoS) using DoDAF." *National Defense Industrial Association Systems Engineering Conference*. Dallas, TX: October 2004.

Diehl, Jeff J. "Exploring the Difference Between Enterprise and System Architectures – A Look at the Different Methods, Tools, and Techniques." *Ground System Architectures Workshop*. El Segundo, CA: The Aerospace Corporation, 2004.

DoD Architecture Framework Working Group. *DoD Architecture Framework Version 1.0, Volume I*. Washington: Department of Defense, 9 February 2004.

DoD Architecture Framework Working Group. *DoD Architecture Framework Version 2.0, Volume II*. Washington: Department of Defense, 9 February 2004.

Eisner, Howard. *Essentials of Project and Systems Engineering Management, 2nd Edition*. New York: John Wiley & Sons, Inc., 2002.

GIG Architecture Version 2, Executive Summary, August 2003.

Hamilton, John, Rosen, Jerome and Summers, Paul; Joint Command & Control Interoperability: Developing Interoperability Metrics

Hilliard, Richard F. "C4ISR Architectures and Software Architectures." *IEEE Architecture Working Group*. No date.

Hilliard, Richard F., Rice, Timothy B., and Schwarm, Stephen C. "The Architectural Metaphor as a Foundation for Systems Engineering." *Proceedings INCOSE '96 Symposium*, Boston, MA, July 1996.

Kasunic, Mark. "Measuring Systems Interoperability: Challenges and Opportunities," Software Engineering Institute, Carnegie Mellon University, 2001.

Kreitman, Kevin B. "Architecture, Enterprise Architecture, Frameworks, and Processes." *Ground Systems Architecture Workshop*. The Aerospace Corporation, 2004.

Levis, Alexander H. Class Notes, SENG 640 Architecting Information Systems. Washington, DC, 2003.

McCaskill, Lawrence P. "Integrated DoD/C4ISR Architectures: It's not *About* the Framework..." *2004 Command and Control Research and Technology Symposium, The Power of Information Age Concepts and Technologies*. Whitney, Bradley, & Brown, Inc., 2004.

Millette, Chad; *Status of Department of Defense Architecture Framework (DoDAF) Implementation within the Aeronautical Systems Center (ASC)*, Mar 2005.

Office of the Assistant Secretary of Defense for Networks and Information Integration; Net-Centric Program Assessment. Washington: Department of Defense, July 2004.

Schekkerman, Jaap; *Enterprise Architecture Score Card*, Version 2.1, 22 February 2004.

Zachman, John A. *Concepts of the Framework for Enterprise Architecture Background, Description and Utility*. White paper,
<http://members.ozemail.com.au/~visible/papers/zachman3.htm>, 26 March 2004.

8 Vita

8.1 Major Jamison

Major Theresa Jamison graduated from the University of Southern Mississippi with a B.S. in Mathematics and was commissioned a second lieutenant in the United States Air Force in May of 1991. Her first assignment was to Kirtland AFB, New Mexico and the Phillips Laboratory as a satellite development engineer. Following tours to Tyndall AFB, Florida doing statistical analysis on air-to-air missiles; the Air Force Academy, Colorado as an Air Officer Commanding; and Los Angeles AFB, California as the Director of Business Operations for Space-Based Radar, Major Jamison was selected to attend AFIT under the relatively new Intermediate Developmental Education (IDE) program.

Following graduation, Major Jamison will stay at Wright-Patterson AFB where she will be in charge of Weapons and Sensors for the Air Force's B-1 Bomber.

8.2 Major Layman

Major Phillip A. Layman graduated from the University of Cincinnati with a B.S. in Aerospace Engineering and was commissioned a second lieutenant in the United States Air Force in June 1991. While serving as a Communications-Systems Program Manager, he volunteered to cross-train as a Space and Missile Officer in 1994. Following training, Major Layman reported to Minot Air Force Base, North Dakota where he held positions as a Missile Combat Crew Commander, Flight Commander and Operations Group Executive Officer. Major Layman next served as Missile Warning Crew Commander and Chief of Standardization and Evaluation at Thule Air Base, Greenland. After his remote tour of duty, he was selected as the Deputy Director, 21st Space Wing Operations

Center at Peterson Air Force Base, Colorado. From there, Major Layman joined the Air Force Space Command Inspector General Team. During that assignment, he was selected to attend Intermediate Developmental Education in AFIT's System Engineering program. After graduation, Major Layman is assigned to United States Strategic Command at Offutt Air Force Base as a Joint Staff Missile Plans Officer.

8.3 *Major Niska*

Major Brice Niska graduated from the University of Minnesota with a B.S. in Aeronautical Engineering and Mechanics and was commissioned an Air Force officer in May of 1991. His first assignment was to the 4950th Test Wing as a Computer Aided Design Engineer. Following tours to Kirtland AFB, New Mexico as a Project Manager; Montgomery, Alabama as a Squadron Officer School Instructor; and Los Angeles AFB, California as a Program Manager for a classified program, Brice was selected to attend AFIT under the relatively new Intermediate Developmental Education (IDE) program. Following graduation, Major Niska will head to Rosslyn, Virginia to be a program element monitor for space at the Under Secretary of the Air Force's Office for Space Acquisition.

8.4 *Major Whitney*

Major Steven P. Whitney graduated from the University of Minnesota with a B.S. in Electrical Engineering and was commissioned a second lieutenant in the United States Air Force in December 1992. Major Whitney's first assignment was to Schriever AFB,

Colorado, where he served as the Chief of Spacecraft Engineering for the Defense Support Program satellites performing missile warning for the US. Following an assignment to the Space Based Infrared Systems Program Office, Steve was selected for the Air Force Intern Program in 1998. As part of this, he served tours in the Secretary of the Air Force's staff in Acquisitions coordinating budgets and policy for space programs and in the Office of the Secretary of Defense writing Department policy on Military Funeral Honors, while completing a M.A. in Administrative Sciences and Leadership Theory from the George Washington University. Just prior to attending AFIT, Major Whitney served as the Director of Engineering at the Air Force Communications Facility at White Sands Missile Range, New Mexico. Upon graduation from AFIT, Major Whitney will report to the Under Secretary of the Air Force's Office for Space Acquisition as a program element monitor for Military SATCOM.

Appendix A: EA Score Card Results

Table 12: C2C EA Score Card Results

Command and Control Constellation (C2C)		Enterprise Architecture Score Card							
		Clear = Well defined and documented						Partially Clear = partially addressed and documented	
ASC	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Business	Information	Information Systems	Technology Infrastructure	Level of Alignment/ Integration	Total Status		
							2	1	0
<i>Questions to the enterprise architecture result</i>						Factor 0-2: 0=Insufficient 1=Average 2=Full			
1	Are the Mission, Vision, Goals, & Objectives of the Enterprise Architecture?	2	2	1	1	0	2	2	0
2	Is the Scope of the enterprise architecture program?	2	2	1	2	1	3	1	0
3	Is the Form & Function Level of deliverables?	1	1	2	1	0	1	3	0
4	Is the Business & IT Strategy?	1	0	0	0	0	0	1	3
5	Are the Guiding Principles & Drivers?	1	1	2	2	1	2	2	0
6	Are the Key Performance Indicators?	0	0	0	1	0	0	1	3
7	Are the Critical Success Factors?	0	0	1	1	0	0	2	2
8	Are the Critical Stakeholders?	1	2	2	1	1	2	2	0
<i>Sub Score Contextual Level</i>		8	8	9	9				
9	Are the Collaborative Parties Involved?	1	2	1	1	1	1	3	0
10	Are the Contractual Agreements?	0	0	0	0	0	0	0	4
11	Are the Interoperability standards?	2	2	2	2	2	4	0	0
12	Are the related Law & Regulations?	2	2	2	2	2	4	0	0
13	Is the Ownership of Information?	2	2	2	2	2	4	0	0
<i>Sub Score Environmental Level</i>		7	8	7	7				
14	Are the Functional Requirements?	2	2	2	2	2	4	0	0
15	Are the Non-Functional Requirements?	2	2	2	2	2	4	0	0
16	Are the concepts in use?	1	0	0	0	0	0	1	3
17	Are the Security Requirements?	1	1	1	1	1	0	4	0
18	Are the Governance Requirements?	1	1	1	1	1	0	4	0
<i>Sub Score Conceptual Level</i>		7	6	6	6				
19	Are the deliverables at logical level?	1	2	2	2	1	3	1	0
20	Are the critical logical design decisions?	2	1	1	1	1	1	3	0
21	Are the critical logical design decisions traceable?	1	0	0	0	0	0	1	3
22	Are the Logical Description Methods & Techniques?	1	0	0	0	0	0	1	3
23	Is at logical level the use of Modeling Tools?	1	0	0	0	0	0	1	3
24	Are the Logical Standards?	0	2	2	2	1	3	0	1
<i>Sub Score Logical Level</i>		6	5	5	5				
25	Are the deliverables at physical level?	1	0	0	0	0	0	1	3
26	Are the critical physical design decision?	0	0	0	0	0	0	0	4

27	Are the critical physical design decisions traceable?	0	0	0	0	0	0	0	4
28	Are the Physical Description Methods & Techniques?	0	0	0	0	0	0	0	4
29	Is at the physical level the use of Modeling tools	0	0	0	0	0	0	0	4
30	Are the Physical Standards?	0	2	2	2	1	1	0	1
<i>Sub Score Physical Level</i>		1	2	2	2				
31	Critical Design Decisions	2	0	0	1	0	1	1	2
32	Is the Organization Impact?	1	1	1	1	0	0	4	0
33	Are the Costs Consequences?	1	0	0	0	1	0	1	3
34	Is the Security Impact?	0	0	0	0	0	0	0	4
35	Is the Governance Impact?	1	0	0	0	0	0	1	3
<i>Sub Score Transformational Level</i>		5	1	1	2				
<i>Total Score All Levels</i>		34	30	30	31				

Table 13: CCIC2S EA Score Card

Combatant Commanders Integrated Command and Control System (CCIC2S)		Enterprise Architecture Score Card							
		Clear = Well defined and documented							
		Partially Clear = partially addressed and documented							
		Unclear = NOT identified or addressed, NOT defined or NOT documented							
	ASC	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Level of Alignment/ Integration	Total Status		
							2	1	0
	<i>Questions to the enterprise architecture result</i>	Business	Information	Information Systems	Technology Infrastructure	Factor 0-2: 0=Insufficient 1=Average 2=Full			
1	Are the Mission, Vision, Goals, & Objectives of the Enterprise Architecture?	2	2	2	2	1	4	0	0
2	Is the Scope of the enterprise architecture program?	2	2	2	2	2	4	0	0
3	Is the Form & Function Level of deliverables?	0	2	2	2	0	3	0	1
4	Is the Business & IT Strategy?	1	2	2	1	1	2	2	0
5	Are the Guiding Principles & Drivers?	1	2	2	2	1	3	1	0
6	Are the Key Performance Indicators?	0	2	2	0	2	2	0	2
7	Are the Critical Success Factors?	1	2	2	2	2	3	1	0
8	Are the Critical Stakeholders?	2	2	2	1	2	3	1	0
<i>Sub Score Contextual Level</i>		9	16	16	12				
9	Are the Collaborative Parties Involved?	0	0	0	1	0	0	1	3
10	Are the Contractual Agreements?	1	0	0	1	0	0	2	2
11	Are the Interoperability standards?	1	2	2	2	1	3	1	0
12	Are the related Law & Regulations?	2	2	2	2	2	4	0	0
13	Is the Ownership of Information?	0	2	1	1	1	1	2	1
<i>Sub Score Environmental Level</i>		4	6	5	7				
14	Are the Functional Requirements?	2	2	2	2	2	4	0	0
15	Are the Non-Functional Requirements?	2	2	2	2	2	4	0	0
16	Are the concepts in use?	1	2	2	1	2	2	2	0
17	Are the Security Requirements?	0	1	1	1	1	0	3	0
18	Are the Governance Requirements?	0	0	1	0	0	0	1	3
<i>Sub Score Conceptual Level</i>		5	7	8	6				

19	Are the deliverables at logical level?	0	0	0	0	0	0	0	4
20	Are the critical logical design decisions?	1	2	0	0	1	1	1	2
21	Are the critical logical design decisions traceable?	0	1	0	0	0	0	1	3
22	Are the Logical Description Methods & Techniques?	1	2	2	2	2	3	1	0
23	Is at logical level the use of Modeling Tools?	0	0	0	0	0	0	0	4
24	Are the Logical Standards?	1	2	2	2	2	3	1	0
<i>Sub Score Logical Level</i>		3	7	4	4				
25	Are the deliverables at physical level?	0	0	0	0	0	0	0	4
26	Are the critical physical design decision?	0	0	0	0	0	0	0	4
27	Are the critical physical design decisions traceable?	0	0	0	0	0	0	0	4
28	Are the Physical Description Methods & Techniques?	0	0	0	0	0	0	0	4
29	Is at the physical level the use of Modeling tools	0	0	0	0	0	0	0	4
30	Are the Physical Standards?	0	1	1	0	1	0	2	2
<i>Sub Score Physical Level</i>		0	1	1	0				
31	Critical Design Decisions	0	0	0	0	0	0	0	4
32	Is the Organization Impact?	1	1	1	1	1	0	4	0
33	Are the Costs Consequences?	1	0	0	0	0	0	1	3
34	Is the Security Impact?	0	0	0	0	0	0	0	4
35	Is the Governance Impact?	0	0	0	0	0	0	0	4
<i>Sub Score Transformational Level</i>		2	1	1	1				
<i>Total Score All Levels</i>		23	38	35	30				

Table 14: GIG EA Score Card Results

Global Information Grid (GIG)		Enterprise Architecture Score Card							
		Clear = Well defined and documented							
		Partially Clear = partially addressed and documented							
		Unclear = NOT identified or addressed, NOT defined or NOT documented							
	ASC	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Status definition: Clear = 2 Partially Clear = 1 Unclear = 0	Level of Alignment/Integration	Total Status		
	<i>Questions to the enterprise architecture result</i>	Business	Information	Information Systems	Technology Infrastructure	Factor 0-2; 0=Insufficient 1=Average 2=Full	2	1	0
1	Are the Mission, Vision, Goals, & Objectives of the Enterprise Architecture?	2	2	2	1	1	3	1	0
2	Is the Scope of the enterprise architecture program?	1	2	2	2	2	3	1	0
3	Is the Form & Function Level of deliverables?	2	1	0	0	0	1	1	2
4	Is the Business & IT Strategy?	2	2	2	1	1	3	1	0
5	Are the Guiding Principles & Drivers?	1	1	1	1	2	0	4	0
6	Are the Key Performance Indicators?	2	2	2	2	2	4	0	0
7	Are the Critical Success Factors?	1	1	1	1	2	0	4	0
8	Are the Critical Stakeholders?	2	2	2	2	2	4	0	0
<i>Sub Score Contextual Level</i>		13	13	12	10				
9	Are the Collaborative Parties Involved?	2	2	2	2	2	4	0	0

10	Are the Contractual Agreements?	1	0	0	0	0	0	1	3
11	Are the Interoperability standards?	1	1	1	1	2	0	4	0
12	Are the related Law & Regulations?	1	1	1	1	2	0	4	0
13	Is the Ownership of Information?	0	1	2	0	0	1	1	2
<i>Sub Score Environmental Level</i>		5	5	6	4				
14	Are the Functional Requirements?	1	1	1	1	2	0	4	0
15	Are the Non-Functional Requirements?	1	2	2	1	1	2	2	0
16	Are the concepts in use?	1	2	2	1	1	2	2	0
17	Are the Security Requirements?	2	2	2	2	2	4	0	0
18	Are the Governance Requirements?	2	1	1	1	1	1	3	0
<i>Sub Score Conceptual Level</i>		7	8	8	6				
19	Are the deliverables at logical level?	1	1	1	1	2	0	4	0
20	Are the critical logical design decisions?	2	1	1	1	1	1	3	0
21	Are the critical logical design decisions traceable?	2	2	2	2	2	4	0	0
22	Are the Logical Description Methods & Techniques?	1	1	2	2	1	2	2	0
23	Is at logical level the use of Modeling Tools?	2	2	2	2	2	4	0	0
24	Are the Logical Standards?	1	1	1	1	2	0	4	0
<i>Sub Score Logical Level</i>		9	8	9	9				
25	Are the deliverables at physical level?	0	0	1	1	0	0	2	2
26	Are the critical physical design decision?	0	0	0	0	0	0	0	4
27	Are the critical physical design decisions traceable?	0	0	0	0	0	0	0	4
28	Are the Physical Description Methods & Techniques?	1	1	1	1	1	0	4	0
29	Is at the physical level the use of Modeling tools	1	2	2	2	1	3	1	0
30	Are the Physical Standards?	1	2	2	2	0	3	1	0
<i>Sub Score Physical Level</i>		3	5	6	6				
31	Critical Design Decisions	1	1	1	1	2	0	4	0
32	Is the Organization Impact?	2	2	2	2	2	4	0	0
33	Are the Costs Consequences?	0	0	0	0	0	0	0	4
34	Is the Security Impact?	2	2	2	2	2	4	0	0
35	Is the Governance Impact?	1	1	1	1	2	0	4	0
<i>Sub Score Transformational Level</i>		6	6	6	6				
<i>Total Score All Levels</i>		43	45	47	41				

References

- ¹ E-mail dated 10 December 2004
- ² Millette, Chad; *Status of Department of Defense Architecture Framework (DoDAF) Implementation within the Aeronautical Systems Center (ASC)*, Mar 2005, p22-24,30.
- ³ Cooper, Cecily D. *Not Just a Numbers Thing: Tactics for Improving Reliability and Validity in Qualitative Research*. Los Angeles, CA: University of Southern California Marshall School of Business, no date.
- ⁴ Chairman Joint Chiefs of Staff (CJCS). Interoperability and Support of Information Technology and National Security Systems. CJCSI 6212.01C Washington: Joint Chiefs of Staff, 20 November 2003.
- ⁵ DoD Architecture Framework Working Group. *DoD Architecture Framework Version 2.0, Volume II*. Washington: Department of Defense, 9 February 2004, pages 2-7.
- ⁶ Chairman Joint Chiefs of Staff (CJCS). Interoperability and Support of Information Technology and National Security Systems. CJCSI 6212.01C Washington: Joint Chiefs of Staff, 20 November 2003
- ⁷ Colombi, John. *System Engineering and System Architecture*. Power Point presentation provided to researcher by author, no date.
- ⁸ Office of the Assistant Secretary of Defense for Networks and Information Integration; *Net-Centric Program Assessment*. Washington: Department of Defense, July 2004, p. ii.
- ⁹ Eisner, Howard. *Essentials of Project and Systems Engineering Management, 2nd Edition*. New York: John Wiley & Sons, Inc., 2002, p 34.
- ¹⁰ Eisner, Howard. *Essentials of Project and Systems Engineering Management, 2nd Edition*. New York: John Wiley & Sons, Inc., 2002, p.41
- ¹¹ Mark Maier and Eberhardt Rechtin *The Art of Systems Architecting*, 2nd Edition. Boca Raton, FL: CRC Press, 2002, p.228
- ¹² Colombi, John. *System Engineering and System Architecture*. Power Point presentation provided to researcher by author, no date.
- ¹³ "Enterprise Architecture For DoD Acquisition", *Defense Acquisition Review Journal*, Spring, 2000 by David P. Brown
- ¹⁴ DoD Architecture Framework Working Group. *DoD Architecture Framework Version 1.0, Volume I*. Washington: Department of Defense, 9 February 2004, Figure 3-7, p 3-12
- ¹⁵ CJCSM 3170.01a, *Operation of the Joint Capabilities Integration and Development System*, 12 Mar 04, p. B-4
- ¹⁶ Maier, Mark and Rechtin, Eberhardt. *The Art of Systems Architecting*, 2nd Edition. Boca Raton, FL: CRC Press, 2002, p223
- ¹⁷ Millette, Chad; *Status of Department of Defense Architecture Framework (DoDAF) Implementation within the Aeronautical Systems Center (ASC)*, Mar 2005
- ¹⁸ DoD Architecture Framework Working Group. *DoD Architecture Framework Version 2.0, Volume II*. Washington: Department of Defense, 9 February 2004, p 1-1
- ¹⁹ DoD Architecture Framework Working Group. *DoD Architecture Framework Version 1.0, Volume I*. Washington: Department of Defense, 9 February 2004, p 3-10
- ²⁰ DoDAF version 1.0, Volume II, p 3-2
- ²¹ DoDAF version 1.0, Volume II, p 3-3
- ²² DoDAF version 1.0, Volume II, p 3-4
- ²³ DoDAF version 1.0, Volume II, p 1-5
- ²⁴ Eisner, Howard. *Essentials of Project and Systems Engineering Management, 2nd Edition*. New York: John Wiley & Sons, Inc., 2002,
- ²⁵ DoDAF version 1.0, Volume I, p 1-6
- ²⁶ DoDAF version 1.0, Volume II, p 1-1
- ²⁷ C2C Overview and Summary Information (AV-1), Version 2.0, 21 November 2003, page 5, paragraph 2.0.
- ²⁸ CCIC2S Operational Architecture User's Guide, 15 March 2004, paragraphs 1.4. – 2.0.
- ²⁹ GIG Architecture Version 2, Executive Summary, August 2003, paragraph 1.
- ³⁰ *Joint Vision 2020*, p.15
- ³¹ *LISI Inspector*, v1.0, August 2000, p1

-
- ³² C4ISR Architecture Working Group, *Levels of Information Systems Interoperability*, 30 Mar 1998, p. 1-3.
- ³³ C4ISR Architecture Working Group, *Levels of Information Systems Interoperability*, 30 Mar 1998, p. ES-4
- ³⁴ C4ISR Architecture working group, *The Levels of Information Systems Interoperability*, 30 Mar 1998, p. 2-9
- ³⁵ C4ISR Architecture working group, *The Levels of Information Systems Interoperability*, 30 Mar 1998, p. 6-3.
- ³⁶ Clark, Thea; Organisational Interoperability Maturity Model for C2, Defence Science and Technology Organisation C3 Research Centre, Fern Hill Park,
- ³⁷ Clark, Thea; Organisational Interoperability Maturity Model for C2, Defence Science and Technology Organisation C3 Research Centre, Fern Hill Park,
- ³⁸ Hamilton, John, Rosen, Jerome and Summers, Paul; Joint Command & Control Interoperability: Developing Interoperability Metrics
- ³⁹ Schekkerman, Jaap; *Enterprise Architecture Score Card*, Version 2.1, 22 February 2004, page 2.
- ⁴⁰ Ibid. page 5.
- ⁴¹ Ibid. page 7.
- ⁴² C2C TCT Overview Briefing, slide 7.
- ⁴³ CCIC2S Operational Architecture White Paper, page 1.

REPORT DOCUMENTATION PAGE				<i>Form Approved</i> <i>OMB No. 074-0188</i>	
<p>The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> <p>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</p>					
1. REPORT DATE (DD-MM-YYYY) 13-0602005		2. REPORT TYPE Master's Thesis		3. DATES COVERED (From – To) Jun 04 – Jun 05	
4. TITLE AND SUBTITLE Evaluation of Enterprise Architecture Interoperability				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Whitney, Steven P., Major, USAF Niska, Brice T., Major, USAF Layman, Phill A., Major, USAF Jamison, Theresa A., Major, USAF				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way WPAFB OH 45433-7765				8. PERFORMING ORGANIZATION REPORT NUMBER AFIT/ISE/ENY/05-J02	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFIT/SY 2950 Hobson Way Wright-Patterson AFB, Ohio 45433				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Currently, Department of Defense (DoD) policy requires programs to develop architectural products as part of programmatic documentation. Specifically, the Joint Capabilities Integration and Development System (JCIDS) and DoD 5000 series requires architecture products at acquisition milestone decisions. The DoD implements a recommended framework, the Department of Defense Architecture Framework (DoDAF), which describes these architectures. The purpose of this project, suggested by Air Force Space Command, was to examine the value of existing analytical tools in making an interoperability assessment of individual enterprises, as well as assess the touch-points between enterprise architectures. This novel evaluation scheme is based solely on the architecture products, rather than the more common assessment via interviews of subject matter experts or actual system testing. If the architecture products required by DoD are to have any merit, their underlining data must be used by decision makers. Well developed architectures can better aid in capability planning, investment decisions (i.e. spiral upgrades), as well as support proposals for integrated Family of Systems solutions by identifying gaps. The project examines the application of two different assessment tools applied to three different enterprise architectures; these included the DoD's Global Information Grid (GIG), the Air Force C2 Constellation (C2C) and the Combatant Commanders Integrated Command and Control System (CCIC2S). Lastly, some suggested recommendations for improving both the architectural products and tools to aid in interoperability assessments.					
15. SUBJECT TERMS Interoperability, Enterprise Architecture, Enterprise Architecture Score Card, Levels of Information Systems Interoperability (LISI), Department of Defense Architecture Framework (DoDAF)					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 81	19a. NAME OF RESPONSIBLE PERSON Lt Col John Colombi
a. REPORT U	U	U			19b. TELEPHONE NUMBER (Include area code) 937-255-3636 x3477 john.colombi@afit.edu