

University of Central Florida

**STARS**

---

Electronic Theses and Dissertations

---

2010

# A Governance Reference Model For Service-oriented Architecture-based Common Data Initialization A Case Study Of Military Simulation Federation Systems

Jeremy Thomas Lanman  
*University of Central Florida*



Part of the [Engineering Commons](#)

Find similar works at: <https://stars.library.ucf.edu/etd>

University of Central Florida Libraries <http://library.ucf.edu>

This Doctoral Dissertation (Open Access) is brought to you for free and open access by STARS. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of STARS. For more information, please contact [STARS@ucf.edu](mailto:STARS@ucf.edu).

---

## STARS Citation

Lanman, Jeremy Thomas, "A Governance Reference Model For Service-oriented Architecture-based Common Data Initialization A Case Study Of Military Simulation Federation Systems" (2010). *Electronic Theses and Dissertations*. 1573.

<https://stars.library.ucf.edu/etd/1573>

A GOVERNANCE REFERENCE MODEL FOR SERVICE-ORIENTED  
ARCHITECTURE-BASED COMMON DATA INITIALIZATION: A CASE STUDY  
OF MILITARY SIMULATION FEDERATION SYSTEMS

by

JEREMY THOMAS LANMAN  
B.S. Butler University, 2001  
M.S.E. Embry-Riddle Aeronautical University, 2003

A dissertation submitted in partial fulfillment of the requirements  
for the degree of Doctor of Philosophy  
in the Department of Modeling and Simulation  
in the College of Engineering and Computer Science  
at the University of Central Florida  
Orlando, Florida

Summer Term  
2010

Major Professor: Michael D. Proctor

© 2010 Jeremy T. Lanman

## **ABSTRACT**

Military simulation and command and control federations have become large, complex distributed systems that integrate with a variety of legacy and current simulations, and real command and control systems locally as well as globally. As these systems continue to become increasingly more complex so does the data that initializes them. This increased complexity has introduced a major problem in data initialization coordination which has been handled by many organizations in various ways. Service-oriented architecture (SOA) solutions have been introduced to promote easier data interoperability through the use of standards-based reusable services and common infrastructure. However, current SOA-based solutions do not incorporate formal governance techniques to drive the architecture in providing reliable, consistent, and timely information exchange. This dissertation identifies the need to establish governance for common data initialization service development oversight, presents current research and applicable solutions that address some aspects of SOA-based federation data service governance, and proposes a governance reference model for development of SOA-based common data initialization services in military simulation and command and control federations.

This dissertation is dedicated to my wife, Apurva, and son, Krishiv. Without their love and support, I could not have completed this work.

## **ACKNOWLEDGEMENTS**

I would like to acknowledge the inspirational instruction and guidance of my advisor and doctoral committee chairman, Dr. Michael Proctor, whose mentorship and constructive feedback instilled high quality into this dissertation. Furthermore, I would like to acknowledge my committee members: Dr. Ratan Guha, Dr. Robert Wittman, Dr. Peter Kincaid, and Dr. Bala Jaganathan for their expert insight and support throughout the process.

## TABLE OF CONTENTS

LIST OF FIGURES .....	x
LIST OF TABLES .....	xii
LIST OF ACRONYMS .....	1
1.0 INTRODUCTION .....	4
1.1 Background and Motivation .....	4
1.2 Problems with Current Approaches .....	8
1.3 Common Data Initialization in Military Simulation and C2 Federation Systems ..	12
1.4 What is a Service Oriented Architecture (SOA)? .....	13
1.4.1 SOA Challenges .....	16
1.4.2 SOA Governance .....	17
1.4.3 SOA Governance Goals and Objectives .....	17
1.4.4 SOA Governance Prerequisites .....	18
1.4.5 Run-time Governance vs. Design-time Governance .....	19
1.4.6 Impacts of Ungoverned SOA-based Solutions .....	20
1.5 Information Agility, Interoperability, and Data Ownership .....	23
1.6 Research Scope .....	25
1.7 Research Issues .....	26
1.8 Organization of the Dissertation .....	28
2.0 RELATED WORK .....	29
2.1 DoD Organizations Sponsoring Common Data Initialization Capability .....	29
2.1.1 U.S. Army: Simulation to C2 Interoperability (SIMCI) .....	29
2.1.2 Joint Forces Command: Joint Rapid Scenario Generation .....	30
2.1.3 U.S. Army: Chief Information Officer Data Initialization Initiative .....	30
2.2 Current and Near-Term Solutions .....	31
2.2.1 Scenario Generation Server (SGS) .....	32
2.2.2 Army C4ISR and Simulation Initialization System (AC SIS) .....	35
2.2.3 Joint Integrated Database Preparation System (JIDPS) .....	38
2.2.4 Unit Order Battle Data Access Tool (UOBDAT) .....	41

2.2.5 Naval Aviation Simulation Master Plan (NASMP) Portable Source Initiative	43
2.2.6 Army Synthetic Environment (SE) Core .....	44
2.2.7 SOF Planning, Rehearsal, Execution Preparation (SOFPREP) .....	44
2.2.8 Geospatial Intelligence Data Management (GIDM) .....	45
2.2.9 Environmental Scenario Generator (ESG).....	46
2.2.10 Joint Event Data Initialization Services (JEDIS).....	48
2.2.11 Strengths of Current and Near-Term Solutions .....	49
2.2.12 Weaknesses of Current and Near-Term Solutions.....	49
2.3 Long-Term Solution.....	50
2.3.1 Objective Initialization Capability (OIC) .....	50
2.3.2 Strengths of Long-Term Solution .....	51
2.3.3 Weaknesses of Long-Term Solution.....	52
2.4 Alternative Approaches .....	52
2.4.1 Software Agents.....	52
2.4.2 Virtualization .....	53
2.4.3 Semantic Web Services.....	54
2.4.4 Non Defense SOA Governance Communities.....	55
2.5 SOA Governance Organizational Best Practices .....	56
2.5.1 Vision and Leadership .....	57
2.5.2 Policy and Security .....	58
2.5.3 Strategy and Roadmap Development.....	59
2.5.4 Acquisition and Behavior.....	60
2.5.5 Implementation and Operations .....	62
2.6 Formats and Standards.....	63
2.7 Argument for a Governance Reference Model.....	66
2.7.1 Description of a New Strategy .....	67
2.7.2 Solution to a Previous Weakness .....	69
3.0 RESEARCH CONCEPT AND METHODOLOGY.....	71
3.1 Research Concept.....	71



3.2 Phase I: SOA Governance Global Analysis Methodology .....	72
3.2.1 Structured Subject Matter Expert Interviews .....	73
3.2.2 Key Factor Analysis .....	78
3.2.3 Issue Documentation .....	79
3.3 Phase II: Design and Documentation Approach of Governance Reference Model	80
3.3.1 Strategy Development .....	80
3.3.2 Modeling Design and Documentation .....	81
3.4 Phase III: Implementation Approach of SOA Governance Prototype .....	82
3.4.1 Requirements for the Prototype .....	83
3.4.2 Governance Reference Model Goals for the Prototype .....	85
3.5 Phase IV: Evaluation Approach of Governance Reference Model .....	87
3.5.1 Verification of the Prototype .....	87
3.5.2 Application-oriented Evaluation Using Goal-Question-Metric Approach .....	90
3.5.3 Validation of the Governance Reference Model .....	95
3.6 Contribution of the Research .....	97
4.0 RESEARCH DATA COLLECTION, ANALYSIS, AND FINDINGS .....	98
4.1 Phase I: SOA Governance Expert Interviews, Findings and Synthesis .....	102
4.1.1 Structured Interviews and Expert Assessments .....	102
4.1.2 Synthesis of Expert Assessments into Governance Design Factors .....	103
4.1.3 Synthesis of Expert Assessments into Governance Design Issues .....	105
4.2 Phase II: Governance Reference Model Issue Resolution and Model Revision ..	105
4.2.1 Model Issue Identification and Resolution: Solutions and Strategies .....	107
4.2.2 Conceptual Governance Reference Model Revisions: Stages and Threads ..	111
4.2.3 Governance Reference Model Developmental Process: Stages and Threads	113
4.2.4 Revised Governance Reference Model: Stages and Threads .....	115
4.3 Phase III: Development and Analysis of Prototype .....	129
4.3.1 Integrated Development Environment Details .....	129
4.3.2 Revised Governance Reference Model Implementation .....	131
4.3.3 Prototype Implementation .....	138

4.4 Phase IV: Evaluation, Verification, and Validation of Governance Reference Model and Prototype.....	146
4.4.1 Verification of the Prototype .....	146
4.4.2 Application-oriented Evaluation Using Goal-Question-Metric Approach ....	151
4.4.3 Validation of the Governance Reference Model.....	155
5.0 CONCLUSION AND FUTURE RESEARCH DIRECTIONS .....	159
5.1 Background Refresh.....	159
5.2 Flow of Research .....	160
5.3 Summary of Findings.....	162
5.4 Original Contributions .....	166
5.5 Solution to a Previous Weakness.....	169
5.6 Limitations of Research and Obstacles to Overcome .....	173
5.7 Future Research Opportunities .....	175
APPENDIX A: STRUCTURED INTERVIEWS .....	178
APPENDIX B: FACTORS & IMPACTS .....	209
APPENDIX C: SOLUTIONS & STRATEGIES.....	223
APPENDIX D: GOVERNANCE REFERENCE MODEL DESIGN & DOCUMENTATION .....	234
APPENDIX E: PROTOTYPE DESIGN & DOCUMENTATION .....	246
LIST OF REFERENCES .....	253

## LIST OF FIGURES

Figure 1: Service Oriented Architecture Concept (Erl, 2007) .....	14
Figure 2: InfoWorld study looking at factors that inhibit SOA adoption .....	16
Figure 3: Notional Initialization Process (Black and Sprinkle, 2006) .....	31
Figure 4: Scenario Generation Server (SGS) Architecture (Szych, 2003) .....	34
Figure 5: Army C4ISR Simulation and Initialization System (AC SIS) Architecture .....	36
Figure 6: Unit Generation Utility (UGU) Data Flow Architecture.....	40
Figure 7: Unit Order Battle Data Access (UOBDA) Architecture (MSCO, 1999) .....	42
Figure 8: Army Objective Initialization Capability (OIC) Architecture (Carleton, 2006).....	51
Figure 9: Initial Conceptual Governance Reference Model for Data Services .....	67
Figure 10: Unified Modeling Language Meta-model Notation .....	82
Figure 11: Use Case Activity Verification Process .....	90
Figure 12: Research Concept and Methodology Phases .....	101
Figure 13: Conceptual Governance Reference Model for Data Services .....	106
Figure 14: High Level Conceptual Governance Reference Model.....	112
Figure 15: Data Services Server Business Process Model.....	132
Figure 16: Governance Registry Business Process Model .....	133
Figure 17: Web Services Application Server Business Process Model.....	134
Figure 18: Business Process Server Business Process Model .....	135
Figure 19: Security Server Business Process Model .....	136
Figure 20: Enterprise Service Bus Business Process Model .....	137
Figure 21: Data Service Console .....	139
Figure 22: Governance Management Console.....	140
Figure 23: Roles and Responsibilities Console - Users .....	141
Figure 24: Roles and Responsibilities Console – Roles .....	141
Figure 25: Roles and Responsibilities Console - Profiles.....	142
Figure 26: Security Console.....	143
Figure 27: Metrics Console.....	144

Figure 28: Registry and Behaviors Console .....	145
Figure 29: InfoWorld study describing factors that inhibit SOA adoption .....	160
Figure 30: Flow of Research Diagram.....	161
Figure 31: High Level Governance Reference Model.....	163
Figure 32: OASIS Reference Architecture Foundation for SOA .....	171
Figure 33: OASIS Governance Reference Model .....	171
Figure 34: SOA Governance Model Comparison.....	172
Figure 35: High Level Conceptual Governance Reference Model.....	235
Figure 36: Data Service Governance Realization Reference Model .....	236
Figure 37: Data Service Governance Execution Reference Model .....	237
Figure 38: Data Service Governance Compliance Enforcement Reference Model .....	238
Figure 39: Data Service Success Factors Reference Model .....	239
Figure 40: Data Services Security Rules Reference Model.....	240
Figure 41: Data Service Policies and Standards Reference Model.....	241
Figure 42: Data Service Processes and Procedures Reference Model.....	242
Figure 43: Data Service Metrics Reference Model.....	243
Figure 44: Data Service Roles and Responsibilities Reference Model .....	244
Figure 45: Data Service Behaviors Reference Model.....	245
Figure 46: Data Services Server Architecture .....	247
Figure 47: Governance Registry Architecture .....	248
Figure 48: Web Services Application Server Architecture.....	249
Figure 49: Business Process Server Architecture .....	250
Figure 50: Security Server Architecture .....	251
Figure 51: Enterprise Service Bus Architecture .....	252

## LIST OF TABLES

Table 1: Sample of DoD M&S Data Initialization File Formats and Standards .....	9
Table 2: Types of Common Data (Wittman, 2006; Tolk, 2007) .....	27
Table 3: Current / Near-Term Solution with Sponsoring Service .....	32
Table 4: Factors Documentation Template.....	79
Table 5: Issue Documentation Template .....	79
Table 6: Strategy Documentation Template .....	81
Table 7: Prototype Requirements Traceability Matrix .....	84
Table 8: Governance Reference Model Goals and Requirements .....	86
Table 9: Prototype Requirements Verification Template .....	88
Table 10: Impact Documentation Template .....	91
Table 11: Goal-Question-Metric Template.....	93
Table 12: Data Service Goal-Question-Metric Matrix (Menasce, 2007; Choi, 2008).....	94
Table 13: Governance Reference Model Goals and Requirements Validation Template	96
Table 14: Governance Reference Model Implementation Matrix .....	131
Table 15: Prototype Implementation Matrix.....	138
Table 16: Prototype Requirements Verification .....	147
Table 17: GQM Metrics Key .....	151
Table 18: GQM Metrics Collected During Subject Matter Expert Evaluation .....	152
Table 19: Baseline Metrics Identified by References .....	152
Table 20: Baseline Average Metrics vs. Prototype Average Metrics Analysis .....	153
Table 21: Governance Reference Model Goals and Requirements Validation .....	157
Table 22: Factor – Incorrect data services and solutions .....	210
Table 23: Factor - Inconsistent approach.....	210
Table 24: Factor - SOA governance approach.....	211
Table 25: Factor - Data services have undocumented ownership.....	211
Table 26: Factor - Unapproved data services are being deployed .....	212
Table 27: Factor - Data services created do not adhere to governance policies .....	212

Table 28: Factor - Data services are not designed, built, and run in a secure manner....	213
Table 29: Factor - Changes to data services are not managed.....	213
Table 30: Factor - Data services are not managed in a scalable way .....	214
Table 31: Factor - Data service developers cannot easily publish and discover services	214
Table 32: Factor - SOA governance controls and policies .....	215
Table 33: Factor - SOA governance roles and responsibilities.....	215
Table 34: Factor - Little vitality in the governance process .....	216
Table 35: Factor - Understanding current governance structures .....	216
Table 36: Factor - Assessing SOA governance maturity.....	217
Table 37: Factor - Developing SOA governance.....	218
Table 38: Factor - Data service identification and appropriate reuse .....	218
Table 39: Factor - Demonstrating the quality of SOA governance solutions.....	219
Table 40: Factor - Data service solution portfolio management.....	219
Table 41: Factor - Ensuring data services satisfy business requirements.....	220
Table 42: Factor - Lack of data service interoperability.....	220
Table 43: Factor - Uncontrolled proliferation of data services.....	221
Table 44: Factor - Cross-organization coordination .....	221
Table 45: Factor - Data service metrics and quantifiable measures .....	222
Table 46: Issue - Adoption of data service governance reference model .....	224
Table 47: Issue - Implementing data service governance .....	225
Table 48: Issue - Executing data service governance .....	226
Table 49: Issue - Enforcing data service governance compliance .....	227
Table 50: Issue - Data service protection via security rules .....	228
Table 51: Issue - Data service enforcement via policies and standards.....	229
Table 52: Issue - Data service implementation via processes and procedures .....	230
Table 53: Issue - Data service management via roles and responsibilities.....	231
Table 54: Issue - Data service monitoring via metrics .....	232
Table 55: Issue - Data service motivation via behaviors .....	233

## **LIST OF ACRONYMS**

ABCS	Army Battle Command System
AC SIS	Army C4I and Simulation Initialization System
BML	Battle Management Language
BPEL	Business Process Execution Language
BPM	Business Process Model
BPMN	Business Process Modeling Notation
C2IEDM	Command and Control Information Exchange Data Model
C2	Command and Control
CBML	Coalition Battle Management Language
CRM	Common Reference Model
CSV	Comma Separated Value
CTSF	Central Technical Support Facility
DIS	Distributed Interactive Simulation
DoD	Department of Defense
FBCB2	Force XXI Battle Command Brigade and Below
ESG	Environmental Scenario Generator
GIDM	Geospatial Intelligence Data Management
GQM	Goal-Question-Metric
G-SOA	Governance-oriented Service Oriented Architecture
HLA	High Level Architecture

ISO	International Organization for Standardization
JCATS	Joint Conflict and Tactical Simulation
JC3IEDM	Joint Consultation, Command, Control, Information Exchange Data Model
JEDIS	Joint Event Data Initialization Services
JIDPS	Joint Integrated Database Preparation System
JRSG	Joint Rapid Scenario Generation
MBDE	Model Based Data Engineering
M&S	Modeling and Simulation
MSCO	Modeling and Simulation Coordination Office
MSDL	Military Scenario Definition Language
NASMP	Navy Air Simulation Master Planner
OASIS	Organization for the Advancement of Structured Information Standards
OBS	Order Battle Simulation
OIC	Objective Initialization Capability
OneSAF	One Semi-Automated Forces
PDU	Protocol Data Unit
RUP	Rational Unified Process
SE Core	Synthetic Environment Core
SGS	Scenario Generation Server
SIMCI	Simulation-to-C4I Interoperability



SISO	Simulation Interoperability Standards Organization
SME	Subject Matter Expert
SOA	Service Oriented Architecture
SOFPREP	Special Operations Framework Planning, Rehearsal, Execution Preparation
TENA	Test and Training Enabling Architecture
TXT	Text
UCOM	Universal Core Object Model
UGU	Unit Generation Utility
UML	Unified Modeling Language
UOBDAT	Unit Order of Battle Data Access Tool
JFCOM	U.S. Joint Forces Command
XML	eXtensible Markup Language

## 1.0 INTRODUCTION

This chapter provides an explanation of the concepts and background information on the technologies used in this research project. The chapter outlines the motivation for the discussion by defining the problems associated with current SOA-based approaches to common data initialization in military simulation and command and control (C2) federation systems. This chapter presents the challenges of SOAs, introduces governance, and describes the impacts of ungoverned services in a SOA environment for simulation and C2 federations. Next, a description of key components of SOA environments that governance proposes to address. Finally, a description of the research issues is presented and the organization of the dissertation is outlined.

### 1.1 Background and Motivation

The Department of Defense (DoD) vision for a common data initialization capability in simulation and command and control (C2) federations is to transition from the current manual stove pipe legacy process to an automated, over the network, service-oriented architecture (SOA). In 2006, the DoD Chief Information Officer published the “Net-Centric Services Strategy” to provide guidance for evolving the DoD net-centric environment to an enterprise SOA. In the document, the DoD states that:

*“As the threats facing the DoD evolve, and as new threats begin to emerge, a new level of responsiveness and agility is required from our forces. The DoD cannot transform its operations to support a net-centric force by merely maintaining and expanding the status quo. Patching stovepipes together*

*is a temporary solution; however, this leads to a fragile environment, which will eventually crumble under the high demands and unpredictable needs of the users. The current DoD network consists of information silos that cannot communicate with each other unless they are pre-wired to do so. In addition, these silos cannot scale to accommodate the levels of interaction that will exist. The DoD's current stovepiped-based information environment must shift to a more robust and agile information environment that can support and enable net-centric operations."* (DoD CIO, 2006).

The scope of this vision encompasses initialization of information systems, common information services, and communications networks (Carlton, 2004; Vietmeyer, 2005; DoD CIO, 2006; DoD Army, 2007). Upon implementation, this capability will potentially support global use, use certified and synchronized authoritative data sources, provide initialization data sets (DoD Army, 2007) to support modular force deployments, and be expandable to new units and systems including Joint, Interagency, Intergovernmental, and Multinational forces (DoD CIO, 2006; DoD Joint, 2005).

Asit, et al. (Asit, 2007) describe an SOA as a new approach to the development of service-based enterprise-wide environments and solutions. The authors claim that SOA will lead to a better alignment of business and IT within an enterprise as it promotes greater agility of loosely-coupled applications as well as it provides opportunities for effective reuse and governance of cross-organizational activities. Since current methods and tools that support SOA development activities have focused primarily on supporting business process and business logic, the authors currently investigate the application of

SOA principles to enable the utilization of data as a service. Dorn, et al. (Dorn, 2007) describe a shift in the information system paradigm from document-centric transactions of business information to process-centric and service-based data exchange. In addition the authors mention that a lot of work has been accomplished in capturing business models and collaborative business processes of an enterprise. On a technical level, Dorn et al. observe that the focus in software development is moving towards service-oriented architectures. The authors also provide a survey and taxonomy of the most promising models and processes at both the business and technical levels. Thomas Erl (Erl, 2007) mentions in his book that “SOA establishes an architectural model that aims to enhance the efficiency, agility and productivity of an enterprise by positioning services as the primary means through which solution logic is represented in support of the realization of strategic goals associated with Service Oriented Computing”. A more formal description of an SOA is provided in the next section.

While the complexity of enterprise SOA may be obtuse, there are many simple examples of SOA implementations used every day. One particular common use is online purchasing. For example, a buyer connects to Amazon.com’s online catalog and chooses a number of items for purchase. The buyer specifies the order through one service, which communicates with an inventory service to find out if the items requested are available in the specifications needed. The order and shipping details are submitted to another service which calculates the total, provide the buyer with delivery details such as when items should arrive, and furnishes a tracking number that, through another service, will allow the buyer to keep track of the order's status and location en route to its final destination.

The entire process, from the initial order to its delivery, is managed by communications between the Web services—programs talking to other programs, all made possible by the underlying framework that SOA provides (Erl, 2007).

SOA enables intrinsic interoperability through the use of standards-based reusable services. Thus, it has been identified as an enabler for Net-Centricity (Mills, 2007). SOA has proven itself as a viable approach to achieving services reuse, application integration and information agility while delivering compelling financial benefits (Erl, 2007).

The DoD Modeling and Simulation Coordination Office also understands the importance of migrating to an SOA and efforts are underway to identify the data services required to support military simulation and C2 systems (DoD Directive, 2007; Tolk, 2007; Tolk, 2003). Additional efforts are ongoing to identify new data services that are required for such systems. Data services supporting these systems need to be governed to ensure that the services can support both the operational and tactical, to ensure interoperability between data services, and to reduce duplication of data services (DoD Directive, 2007; DoD CIO, 2006).

Various SOA-based solutions have been proposed to address the following common data initialization problems:

- Production of network-centric system architectures and simulation and C2 initialization data products for real-world operations, mission rehearsal, and training exercises is problematic and time consuming (Tolk, 2004; Hieb, 1999; Shane, 2002; Carleton, 2004).

- Legacy system initialization process is complex, de-centralized, sequential, primarily manual, and lacks governance which yields data inconsistencies between simulation and C2 systems (Hieb, 1999; Blalock, 2006; Black, 2006).
- Current force timelines require initialization data products to be generated and synchronized in a number of days. Current processes require a number of weeks or months (Black, 2006; Tolk, 2007).
- Scope of problem will continue to grow as more simulation and C2 systems are fielded across the military services, and new systems are developed and fielded (Tolk, 2006; Vietmeyer, 2005; Hieb, 1999).

The above issues clearly point to the need for common interoperability among data providers and integrators, and for creating a governance reference model.

## 1.2 Problems with Current Approaches

Military simulation and C2 federation systems have long evolved into distributed applications, compatible with various distributed systems architectures but with limited data interoperability. As a result, SOA-based solutions have been introduced to fill the gap, and the various military services and research groups have developed their own databases along with various data access, management, and manipulation tools and services (Black, 2006; Blalock, 2005). However because of the evolving design of these applications, interoperability at the *application* level has always been a significant bottleneck (Vietmeyer, 2005), (Black, 2006).

Also observed was the same interoperability problem at the *data* level. Tolk explains that this is perhaps due to the aggressive policies DoD organizations have embarked in

early years of the simulation and C2 federation development to quickly provide training systems to the warfighter (Tolk, 2003). There are numerous ways of describing common data in various formats such as text (TXT) files, comma-separated values (CSV) files, and eXtensible markup language (XML) files, and standards such as Joint Consultation, Command, Control, Information Exchange Data Model (JC3IEDM), Battle Management Language (BML), and Military Scenario Definition Language (MSDL). Table 1 gives a sample comparison of some of the military simulation and C2 federation data initialization file formats and standards:

Table 1: Sample of DoD M&S Data Initialization File Formats and Standards

Simulation	Flat File Formats									Standards			
	txt	csv	fplan	fchar	terrain	param	phpk	tif	sif	JC3IEDM	MSDL	XML	BML
ONESAF	x										x	x	
JCATS	x	x	x		x	x	x					x	
FIRESIM	x	x										x	
TACSIM	x	x						x					
EADSIM	x	x										x	
CBS	x								x			x	
JDLM	x	x										x	

The unique properties and semantics of the common data such as different fidelities and naming conventions of the same domain caused data service providers to create different ways for describing the same initialized entity which in turn resulted in numerous incompatible formats (Tolk, 2003; Black, 2006).

Several problems with the current SOA-based approaches are identified below:

1. Problems with assembling data: Because of the distributed nature of common data, users are required to utilize different tools to access data in various file

transfer protocol or hyper-text transfer protocol servers, relational or XML databases, etc (Tolk, 2003; Tolk, 2007; Black, 2006).

2. Data format problems: Depending on the user's choice of software, applications that digest common data require input in different formats. Users spend a significant amount of time converting data from one format to other to make it available for their purpose (Carleton, et al., 2004).
3. Amount of resources for processing data: After the data is collected and converted into a usable format, enough hardware and software resources need to be allocated for analyzing (verification and validation) the data. In some cases the amount of collected data reaches to an amount in the order of gigabytes or even terabytes, handling this data becomes a challenge for most users and organizations (Carleton, et. al, 2004; Black, 2006; Tolk, et. al, 2007).
4. Lack of governance: As stated earlier, the process is mostly manual and error-prone; thus, allowing for inconsistent data (Black, 2006).
5. Consistent semantic use of the data across all users of the data: For example, two simulations/federates may model the same platform or phenomena at different levels of resolution and some may use input parameters as keys to their own internal data whereas others may use the values as the final input data (Wittman, 2008).
6. Data model consistency with international interoperability data model standards such as JC3IEDM and another new evolving standard, the Universal Core Object Model (UCOM) (Wittman, 2008).



As a result, today, due to the distributed nature of the common data and the variety of data and application standards the DoD M&S community faces the following challenges:

1. Adoption of universal standards: Over the years DoD organizations have produced common data in specialized formats and developed data services by adhering to differing methodologies (MSDL, 2006; Tolk, et. al, 2007);
2. Distributed nature of common data: Because the data sources are owned and operated by individual DoD groups or organizations, common data is in vastly distributed repositories (Black, 2006; Tolk, 2006),
3. Service interoperability: Computational resources used to initialize common data are also distributed and require the ability to be integrated when necessary (Tolk, 2007).
4. Data agreements: Cleanly determining what is initialization data across dimensions accounting for simulation resolution; model specific data; scenario specific data; exercise control data; etc (Wittman, 2008).

Undoubtedly these issues are the focal point of numerous research and development efforts. Especially the problems related to data formats and standards are being addressed by a number of groups and organizations some of which also offer solutions to the application level interoperability issues. These standards based efforts are summarized in Chapter 2.

However most of the SOA-based common data initialization approaches lack the oversight needed to develop data services (Tolk, et. al, 2007; Black, 2006; Sprinkle, et al., 2005).

### **1.3 Common Data Initialization in Military Simulation and C2 Federation Systems**

Computer applications and system developers, trainers and testers each know what “initialization” means to them within their domain. However, since everyone’s background is unique, there exist many different interpretations. To build understanding, subject matter experts Chris Black and Ronald Sprinkle begin with the following definition for a single computer (Black and Sprinkle, 2006).

*“Initialization is the process of locating and using the defined values for variable data that is used by a computer program.”*

To describe initialization of a networked combat force or a simulation and C2 federation this definition is too primitive. Initialization to enable system of systems applications to perform their intended tasks will not be complete until the network and all involved systems contain consistent data. With this understanding, Black and Sprinkle modify the previous definition as follows:

*“Initialization is the process of consuming distributed defined data enabling separate networked information system users to begin synchronized operational, test or training activities.”*

This definition sets the foundation for this complex topic. The rest of this section continues by describing more of the fundamental aspects of initialization. The purpose of initialization is to automate the data input to achieve system or system of systems startup conditions. Automation is essential to reduce initialization errors, time, and facilitate distribution (Black and Sprinkle, 2006).

Initialization is all about data. In the context of this dissertation, the repositories, tools, process, formats, and dissemination are in support of the end product, which is consistent and accurate data to support synchronized operations, tests, or training activities in a simulation and C2 federation.

The next section will describe a service oriented architecture and list the concept's potential benefits and weaknesses. Furthermore, we will investigate SOA governance, impacts of ungoverned SOA-based solutions, information agility, interoperability, data ownership, and policies.

#### **1.4 What is a Service Oriented Architecture (SOA)?**

The Organization for the Advancement of Structured Information Standards, a not-for-profit consortium that drives the development, convergence and adoption of open standards for the global information society, defines SOA as:

“A paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains. It provides a uniform means to offer, discover, interact with, and use capabilities to produce desired effects consistent with measurable preconditions and expectations.” (OASIS, 2006).

SOA is an architectural and design discipline conceived to achieve the goals of increased interoperability (information exchange, reusability, and composability), increased federation (uniting resources and applications while maintaining their individual autonomy and self-governance), and increased business and technology domain alignment from a set of universally interconnected and interdependent building

blocks, called services (Erl, 2007). A service comprises a stand-alone unit of functionality available only via a formally defined interface (Erl, 2007).

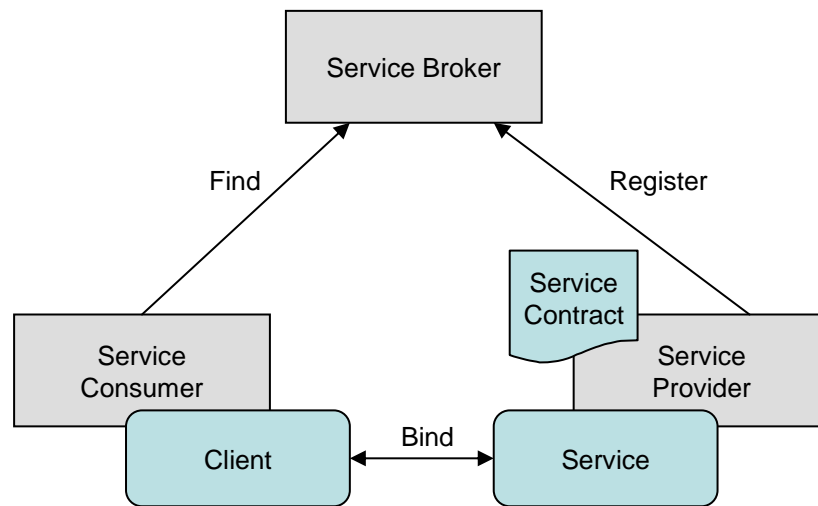


Figure 1: Service Oriented Architecture Concept (Erl, 2007)

Figure 1 describes the fundamental components of a SOA as building blocks. Each SOA building block can play one or more of three roles (Dorn, 2007; Jones, 2005; Erl, 2007):

1. *Service provider*: The service provider creates a Web service and possibly publishes its interface and access information to the service registry. Each provider must decide which services to expose, how to make trade-offs between security and easy availability, how to price the services, or, if they are free, how to exploit them for other value. The provider also has to decide what category the service should be listed in for a given broker service and what sort of trading partner agreements are required to use the service.

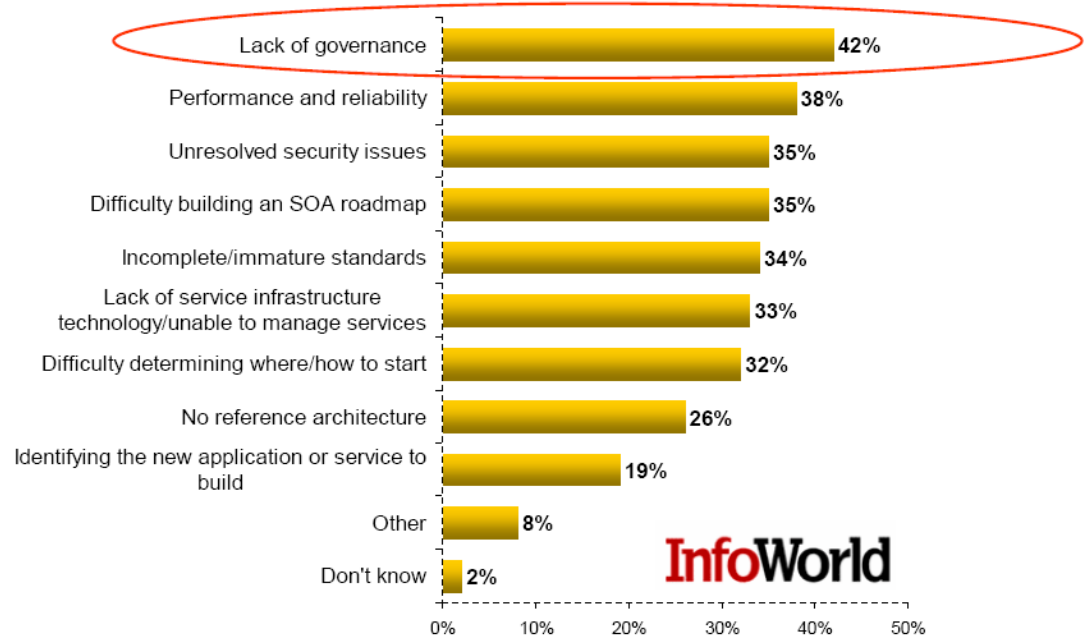
2. *Service broker*: The service broker, also known as service registry, is responsible for making the Web service interface and implementation access information available to any potential service requestor. The implementer of the broker decides about the scope of the broker. Public brokers are available through the Internet, while private brokers are only accessible to a limited audience, for example, users of a company intranet. Furthermore, the amount of the offered information has to be decided. Some brokers specialize in many listings. Others offer high levels of trust in the listed services. Some cover a broad landscape of services and others focus within an industry. There are also brokers that catalog other brokers. Depending on the business model, brokers can attempt to maximize look-up requests, number of listings or accuracy of the listings. The Universal Description Discovery and Integration specification defines a way to publish and discover information about web services.
3. *Service consumer/requestor*: The service consumer/requestor or Web service client locates entries in the broker registry using various find operations and then binds to the service provider in order to invoke one of its Web services.

SOA realizes its business and technical benefits through utilizing an analysis and design methodology (i.e. establishing governance) when creating services that ensures they are consistent with the architectural vision and roadmap and adhere to principles of service-orientation (OASIS, 2006; IBM, 2006). Arguments supporting the business and management aspects from SOA are outlined in various publications (Erl, 2007; Papazoglou, 2007; Bieberstein, 2007; Josuttis, 2007).

### 1.4.1 SOA Challenges

Industry and government sectors implementing SOAs have found that governance is one of the most important topics associated with achieving a successful Network-Centric Environment. An InfoWorld study released in July 2006 (see figure 2) determined that 42% of the projects examined identified a lack of governance to be the largest factor inhibiting SOA adoption (InfoWorld, 2006).

## Factors that inhibit SOA adoption



Source: InfoWorld Research Report: SOA July 2006

Figure 2: InfoWorld study looking at factors that inhibit SOA adoption

### **1.4.2 SOA Governance**

While it may seem obvious that a federation composed of possibly reused, independent and self-governed entities would face governance challenges, a level of governance is necessary. Governance is the intentional usage of policies, plans, procedures, and organizational structures to make decisions and control an entity to achieve the objectives of the organization (IBM, 2006). SOA governance focuses on the services that need to be or are created in the realization of an SOA. A major reason to have an SOA is to create business, technical, and information agility (Papazoglou, 2007; Bieberstein, 2007). In the context of joint military simulation federations, SOA is a reusable services approach to implementing the operational and tactical strategy using the federation (enterprise) architecture (Gartner, 2007). Creating an environment in which reusable data services flourish and the benefits are fully realized requires a well thought-out, explicit, implemented, and maintained governance plan.

The approach to governance in this dissertation emphasizes incentivizing, designing, and executing policies and processes to obtain federation behavior that tends to be (or become) good in the context of the relevant operational, tactical, technical, and human factors. SOA governance of data services is not a single registry or tool used for management. SOA governance is the management of key assets owned by a federation to promote and enforce their use for maximum enterprise benefit and interoperability.

### **1.4.3 SOA Governance Goals and Objectives**

The goal of SOA governance is to develop processes and oversight to ensure that services are developed and sustained to promote a flexible and dynamic infrastructure

(Josuttis, 2007). The governance process itself should be thought of as 80% behavior and 20% technology (IBM, 2006; Josuttis, 2007; Gartner, 2007). Though tools exist to assist in governing services, a governance process must be a normal part of the day-to-day operations within any organization to ensure that all of the services are being built and maintained in a manner that promotes interoperability (Gartner, 2007).

The objectives of SOA governance include (Erl, 2007; OASIS, 2006; Gartner, 2007):

- Encouraging desirable behaviors in SOA – Services are presented to consumers in a standardized manner allowing them to be quickly consumed.
- Maintaining consistency and relevance within the SOA life cycle – Requiring that certain criteria be met before moving to the next cycle ensures that the services being exposed meet a minimum level of maturity.
- Tracing operational goals and capabilities to services – Defined capabilities are mapped to candidate services.
- Measuring the results of those services – Measuring the results of the services allows for them to be prioritized. This helps to ensure that the most important services are addressed and fielded first.

#### **1.4.4 SOA Governance Prerequisites**

For a successful governance structure to be established, certain prerequisites must be met so simulation federation systems can realize the advantages associated with a network-centric architecture (e.g., adaptability, extensibility, etc.). These prerequisites include (Erl, 2007; Bieberstein, 2007; Josuttis, 2007; Gartner, 2007):



- Support and commitment from senior management – Commitment from senior leadership is required to empower a governance committee. Empowerment from senior leadership ensures participants adhere to a committee decision.
- Defining an accepted SOA vision (federation architecture) – Agreed-upon federation architectures ensure participant development towards a common end state. The architecture is a way to identify current and future capabilities.
- Existing data governance and decision-making frameworks – A SOA governance committee needs decision-making authority.

#### **1.4.5 Run-time Governance vs. Design-time Governance**

Run-time Governance vs. Design-time Governance are essential aspects of SOA governance.

Design-time governance is used to manage and streamline the design and development of services and other software development assets (Bieberstein, 2007). For simulation and C2 federations, design-time governance attempts to design an SOA to consistently capture, automatically deliver and apply knowledge across the entire federation.

Run-time governance manages available deployed services (Bieberstein, 2007). Run-time management ensures that the deployed data services (and composite applications built to use those services) are operating effectively with sufficient performance, throughput and security (Gartner, 2007) to meet a federation's operational and tactical objectives. A good analogy is Windows registry, which is used to manage the list of installed programs and some of their configuration settings. Run-time

governance not only manages access to deployed services, but also gathers and presents information about the performance and availability of those services, typically via integration with Web Services (IBM, 2006; Josuttis, 2007). Run-time governance has mostly been established for many of the available SOA-based data services in simulation federations by implementing Model-Based Data Engineering (MBDE) methods as described by Tolk in (Tolk, 2005; Tolk, 2008; Tolk, 2006).

Due to an emerging need to develop new data services, design-time governance has become more necessary (Tolk, 2005). As data services are identified and new data services are developed, there is no control or management for the service development life cycle. Thus, there is a need to focus more on the design-time governance of data services for SOA-based data initialization of simulation and C2 federations.

#### **1.4.6 Impacts of Ungoverned SOA-based Solutions**

An ungoverned SOA can become a liability for the federation, adding cost and disrupting processes. The Gartner Group estimates that a lack of working governance mechanisms in mid- to large-size (greater than 50 services) SOA projects is the most common reason for project failure (Gartner, 2007). A key goal of a governance model is minimizing risk by defining a SOA strategy that builds governance into a federation.

The need for SOA Governance is business-oriented. In moving towards SOA, organizations want to ensure continuity of business operations, manage security exposure, align technology implementation with business requirements, manage liabilities and dependencies, and reduce the cost of operations.

The impact of ungoverned integration projects can be significant to an organization's operations, as AT&T Wireless recently experienced with its new system roll out:

*"The breakdown couldn't have come at a worse time for AT&T Wireless.*

*It deprived the Telco of thousands of potential new customers and cost the company an estimated \$100 million in lost revenue (AT&T, 2004)."*

The failure to govern the evolving SOA can result in millions of dollars in costly service redesigns, maintenance, and project delays. More damaging is the potential loss of revenue, training opportunities and the organization liabilities. SOA represents a new layer of Services that need to be carefully created and managed (Gartner, 2005).

Not developing a governance reference model or having a weak governance reference model for a SOA-based simulation federation will negatively affect development and horizontal integration. Effects from weak or missing SOA governance include (Papazoglou, 2007; Bieberstein, 2007; Josuttis, 2007):

- A lack of trust in data service offerings, causing consumers to not reuse services because of unpredictable quality and performance issues – Governance reference models force different federates to interact to meet a common goal. Not having a SOA governance reference model would allow the federate to develop their own specific integrated architectures that do not support the larger federation. The federate-specific integrated architectures, over time, will create stove-piped (but net-centric) environments in which consumers build their own data services. Even though similar data services may be available within another federate or

federation, they might not be used because of an impression that those data services could change and adversely affect the SOA.

- A disruption in operations and processes from publishing data services that fail to assess the impact of a change – Data services can be changed easily and it is possible for modified data services to disrupt the whole SOA. A set of processes and metrics needs to be in place to ensure that the risks to the SOA from evolving data services are mitigated. A tracking service, for example, can be modified to meet the needs of a subset of users, but adversely affect all of the dependent services because the data model was modified.
- A lack of interoperability through the creation of data service stovepipes, which perpetuate the challenges of a traditional, tightly coupled architecture – Data interoperability is required by governance committees to prevent stovepipes. SOA functionality would be adversely affected if ungoverned data services are published into the federation and programs begin developing to the data service. If a program wanted to migrate away, then additional development funds would be required when the data service interface could have been standardized in the beginning.
- Non-compliance with regulations by failing to associate key policies with data services – Data services can be developed without adhering to a set of mandates or policies. Not adhering to certain policies may require additional hardware or software by users to support special configurations, thereby raising license and sustainment costs for the project.

- Security breaches through uncontrolled data service access – The combined operational and tactical federation may require certain security policies or best-practices be met for specific data services due to classification requirements. In this case, there will not be a committee to ensure that the specific data services meet the standards required.

The next chapter will discuss current SOA-based solutions that have been implemented to address common data initialization issues. These solutions and their respective implementations will be described in detail, and a list of their benefits and weaknesses will be provided.

### **1.5 Information Agility, Interoperability, and Data Ownership**

In the context of SOA governance, information agility is the ability to understand (OASIS, 2006), control (Bieberstein, 2007), and leverage the information assets (OASIS, 2006; Josuttis, 2007) of the organization (federation) in a useable and readily adaptable manner. Information agility tends to be the “redheaded stepchild” of the SOA strategy. This is unfortunate and needs to be corrected by SOA governance, because there is tremendous leverage in a well thought-out and implemented information strategy as part of the federation SOA strategy. It is well known within the DoD M&S community that application integration is a nontrivial problem to solve (Furness, 2006). Applications have usually been developed without benefit of an enforced enterprise data model. Many simulation and C2 systems come with their own data schema and an implied functional process, which the federation developers must either adapt to or engage in an expensive process of adapting to the current federation activity model (Black, 2006). Of course,

this is a process that keeps on giving pain. Further adaptation is necessary whenever either a new release of a federate must be implemented or changes to the business operations cause enhancements to the data structure.

The usual solution for simulation and C2 integration has been point-to-point interface solutions. Such solutions, while operationally efficient, result in an ossification of the federation data model (Furness, 2006). It is expensive and risky to change out one system for another or even make changes to an existing system because of the complex nature of the information and functional model. Changes to one system's interface can result in multiple changes and testing of all the myriad systems that must adapt to this change (Black, 2006).

More generically, the following are regarded as typical problems that most federations must deal with (Carlton, 2004; Furness, 2006; Black, 2006):

- A multitude of technologies and platforms support the simulation and C2 systems.
- Federation process models include a mixture of people practices, application code, and interactions between people and systems or systems of systems.
- Changes to one system tend to imply ripples of changes at many levels and to many other systems.
- No single, fully functional solution will “talk to” or work with all other functional solutions.
- Deployment of any single, proprietary integration solutions across the federation is complex, costly, and time-consuming.

- No single data, organization, or process reference model spans, much less extends beyond, the federation.

In run-time governance, Tolk and Diallo, describe Model-Based Data Engineering (MBDE) for web services in an SOA for better data management in support of semantic definition in information exchange (Tolk, 2006). MBDE provides some process management through a Common Reference Model (CRM) at run-time; which in the case for simulation federations is the JC3IEDM (Tolk, 2005; Tolk, 2008).

SOA stresses interoperability as one of its key principles (Erl, 2007). Interoperability refers to the ability of services deployed using different technologies and platforms to communicate with each other (Papazoglou, 2007). SOA governance can help drive data initialization by demanding and directing this as part of the SOA journey. Data ownership is another key concern for SOA governance. Many different simulation federates will claim to be the primary user and therefore owner of a particular set of data (Erl, 2007; Bieberstein, 2007). SOA design-time governance should seek to identify the owner of each major information area. This will become important in the future as hard decisions need to be made to rationalize this information and enable information agility.

## **1.6 Research Scope**

The scope of this research is limited to constructive simulation and C2 federations and their respective SOA-based common data initialization issues. There are many other and important aspects to consider in future research such as the common data initialization of live and virtual federation simulations, and non-data services. An objective of this research is to provide a governance reference model that can be modified

such that other types of federation simulations can adopt the proposed approach. Also this research is limited to design-time governance of a constructive simulation federation; thus, run-time governance issues will not be addressed. This research will propose a governance reference model for SOA-based common data initialization services in military simulation and C2 federation systems.

### **1.7 Research Issues**

This dissertation will investigate the issues pertaining to SOA-based common data initialization of simulation and C2 federations approaches and propose solutions to these problems based on modern SOA governance approaches.

The importance of providing access to common data services has been central in many research efforts in the DoD M&S community. Another such important issue is distributed access to common data stored in various types of databases. Military simulation and C2 federation systems are especially affected by the developments in both of these areas since these systems are traditionally data-centric (Tolk, 2007); they require access to data from many different sources for creating layers, and tend to use various types of data processing tools and services for analysis or initialization of the common data (Tolk, 2005; Black, 2006).

Distributed data access in simulation and C2 federations is traditionally regarded as dealing with distributed data archives, databases or files which may take weeks or even months to formulate and initialize common data (Tolk, 2007), (Black and Sprinkle, 2006). However training objectives especially during wartime require faster initialization of training applications (Black and Sprinkle, 2006). Presumably, faster initialization of



common data for simulations before exercise execution will provide lower cost to an organization and more time for warfighter training opportunities.

Various types of common data were identified based on their sources:

Table 2: Types of Common Data (Wittman, 2006; Tolk, 2007)

<b>Entity and Organizational Data</b>	<b>Physical Model Data</b>	<b>Behavior Model Data</b>	<b>Environmental Data</b>	<b>C2 Interface Data</b>	<b>Simulation Data</b>	<b>Federation Data</b>
Entity Equipment (C2, Weapons, Sensors)	Ph/Pk Tables	Weapon Selection	Elevation	Live Systems (addressing)	Application to hardware	Multi-sim coordination
Entity and Organization Structure and Relationships	Mobility Data	Formation	Feature	Message types and data	Data Collection	HLA, TENA, DIS PDU's
	Vulnerability	Planning	Buildings, Tunnels, Minefields		Data Storage	
	Rate of Fire	Orders	Weather		Rate of Execution	
		Reporting				

This dissertation is about developing a governance reference model for SOA-based data services that provide access to various types of the common data products, manage data sources, connect them to the simulation applications, allow users to access them in common formats, and initialize the simulation federation during a training exercise. The dissertation implementation encompasses development of common data initialization services by integrating governance components in a simulation federation environment.

The following research questions are identified in the scope of this dissertation:

- Can we incorporate governance in the SOA-based common data initialization process for simulation and C2 federations?

- How can we incorporate widely accepted M&S data industry standards with SOA-based common data initialization services?
- Can we organize and manage the development of SOA-based common data initialization services using a governance reference model? Is a governance reference model appropriate?

### **1.8 Organization of the Dissertation**

This dissertation is organized as follows. The first chapter consists of an overview of SOA-based common data initialization of military simulation and C2 federation systems, a description of SOA and governance, a summary of the outstanding issues that relate to the research outlined in this dissertation, and the research questions. Chapter 2 contains brief reviews of some of the related work. Chapter 3 describes the research concept and methodology. Chapter 4 presents the results on the implementation and analysis of the governance reference model and prototype. Chapter 5 provides answers to the research questions identified in Chapter 1, outlines future research opportunities, and provides conclusion on the research accomplished.

## **2.0 RELATED WORK**

This chapter provides an examination of the various strategies to initialize common data in military simulation and C2 federations. It examines the work accomplished as a product of the collaboration of the various DoD organizations. Questions and remaining research areas identified by the literature are listed. Finally an argument is made for the necessity of a governance reference model for SOA-based common data initialization services in military simulation federations, detailing the problems it addresses and the benefits it provides.

### **2.1 DoD Organizations Sponsoring Common Data Initialization Capability**

This data issue goes beyond any one specific military simulation federation, but is also a focus of the Joint Services community. Thus, there are many efforts working to solve the problem. The following describes applications and organizations that are providing solutions to common data initialization:

#### **2.1.1 U.S. Army: Simulation to C2 Interoperability (SIMCI)**

The Simulation to C2 Interoperability (SIMCI) Overarching Integrated Product Team is a U.S. Army organization and process for improving interoperability between current and future modeling and simulation, and C2 systems. Co-chaired by both of the Army's Program Executive Office, Simulation, Training and Instrumentation and Program Executive Office, Command, Control, Communications, Tactical, the

organization makes recommendations to Army leadership on how to improve interoperability (Carleton, 2006; Shane, et. al, 2005).

### **2.1.2 Joint Forces Command: Joint Rapid Scenario Generation**

The Joint Forces Command (JFCOM) is currently sponsoring the development of an initial prototype, requirements gathering effort, and evaluation of alternatives for a new data source aggregation capability. The purpose of the Joint Rapid Scenario Generation (JRSJ) program is to provide an enterprise approach to implement integrated technologies, standards, architectures, and processes built around an operational requirement to rapidly produce event-ready initialization data sets supporting scenario generation (JFCOM, 2007).

### **2.1.3 U.S. Army: Chief Information Officer Data Initialization Initiative**

The Army Chief Information Officer's white paper, "Army Initialization Capability Strategic Approach" (Blalock, 2005), stated, "The current process is a stove-pipe, head-toe oriented process which lacks the framework to support expanded operations in a Net-Centric environment." The Army Chief Information Officer understood that although there were several efforts addressing the initialization problem it was being attacked piecemeal without a coherent approach to solving the Army's initialization problem, especially in a net-centric environment. The initiative presented the *Notional Initialization Process* describing initialization using four different views (authoritative, integrated, mission-specific, and run time application) and the related processes needed to develop those views. It is a data-centric process view (Blalock,

2005). SIMCI examined the notional process using four static views: data needs, initialization tools, data format/standards, and data dissemination in order to build the ASCIS system (Black and Sprinkle, 2006; Carleton, 2006).

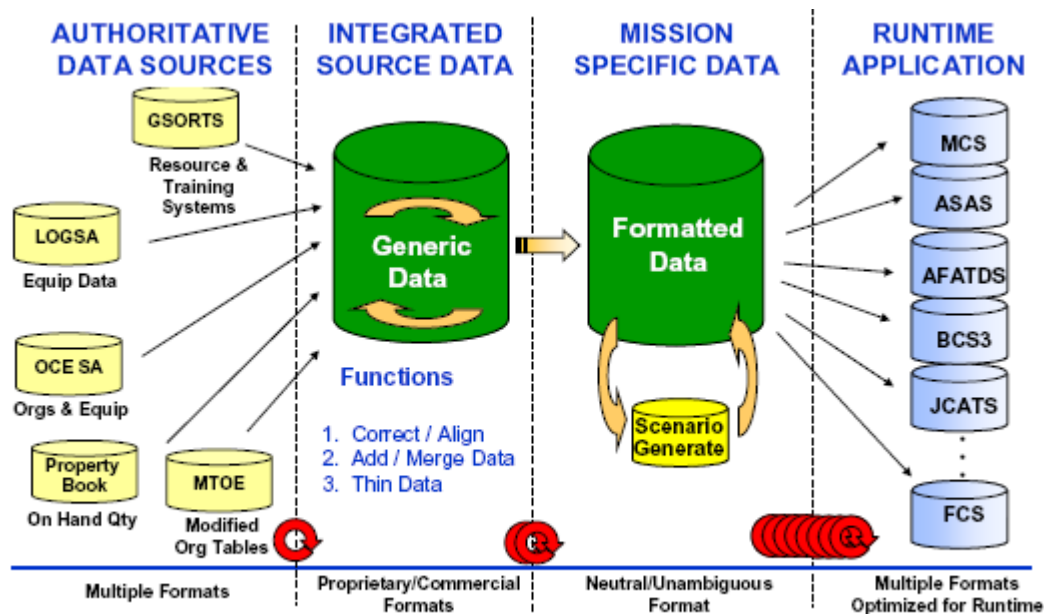


Figure 3: Notional Initialization Process (Black and Sprinkle, 2006)

## 2.2 Current and Near-Term Solutions

There exist several solutions to “pieces” of the common data initialization problem. The following sections describe systems that provide common data sources and tools for joint federations. However, most of the following solutions provide data initialization products, none provide a framework for data initialization services that automate a federation’s initialization process.

Table 3: Current / Near-Term Solution with Sponsoring Service

	Service					
	Army	Air Force	Navy	Marine Corps	Joint	Other
USAF Scenario Generation Server (SGS)		x				
Army C4I & Simulations Initialization System (AC SIS)	x					
Joint Training Data Services (JTDS) (aka Joint Initialization Database Preparation System (JIDPS))					x	
Unit Order of Battle Data Access Tool (UOBDAT)					x	x
Naval Aviation Simulation Master Plan (NASMP) Portable Source Initiative (N-PSI)			x			
Army Synthetic Environment (SE) Core program.	x					
SOF Planning, Rehearsal, Execution Preparation (SOFPREP)						x
Geospatial Intelligence Development System (GIDS)/ Geospatial Intelligence Data Management (GIDM)					x	
Environmental Scenario Generator (ESG)						x

### 2.2.1 Scenario Generation Server (SGS)

SGS is a centralized repository with data management tools that stores and manipulates scenario data from C4I databases, simulation systems, and other third-party scenario-editing tools. SGS enables the initialization of multiple computer-based systems (including both simulation and C2 systems) participating in a distributed training exercise with a single, unified order-of-battle-focused scenario. SGS enables the initialization of multiple computer-based systems (including both simulation and C4I systems) participating in Distributed Mission Operations events with a single, unified order-of-battle-focused scenario. Scenario data is stored internally and processed by SGS in SGS

Data Interchange Format XML files. SGS consists of two sub-applications, SGS Server and SGS Workstation, which both manipulate SGS files. The SGS Server provides gateways that broker communication between SGS and various targeted external systems, while the SGS Workstation provides capabilities to create and edit files retrieved from the SGS Server. Secondly, the SGS provides a mechanism to convert specially-annotated FalconView Drawing Editor drawing files into Airspace Control Order files (Szych, 2003).

SGS Server currently contains gateways to several external systems supported natively including Air Warfare Simulation, Next Generation Threat System, Theater Battle Management Core Systems, Total Army Personnel Database, Air Operations Database, Military Intelligence Database, Portable Flight Planning System, Distributed Information Warfare Constructive Environment and others, with additional systems to be added in future development phases. Other external systems not directly supported by a gateway in the SGS Server can supply data to SGS by providing a means to convert its own internal data representation of Unit Order of Battle to SGS data-formatted XML. Systems can consume data produced by the SGS by providing a means to convert SGS data-formatted XML back into that system's internal data representation. Because asset names and types can differ from system to system, the SGS Workstation contains a name mapping tool called the Translation Editor, which allows users to translate entity names into formats that the user specifies that are suitable for use in the external system of their choosing. A collection of translated asset names is called a Translation Set. Users can

apply Translation Sets to a SGS data set stored in the SGS Server prior to loading that data set into an external system (Szych, 2003).

The SGS can be deployed in a Windows or Linux environment. SGS clients can access the server from any operating environment that contains a web browser, Java 1.4+ installed and a connection to the Scenario Generation Web Server.

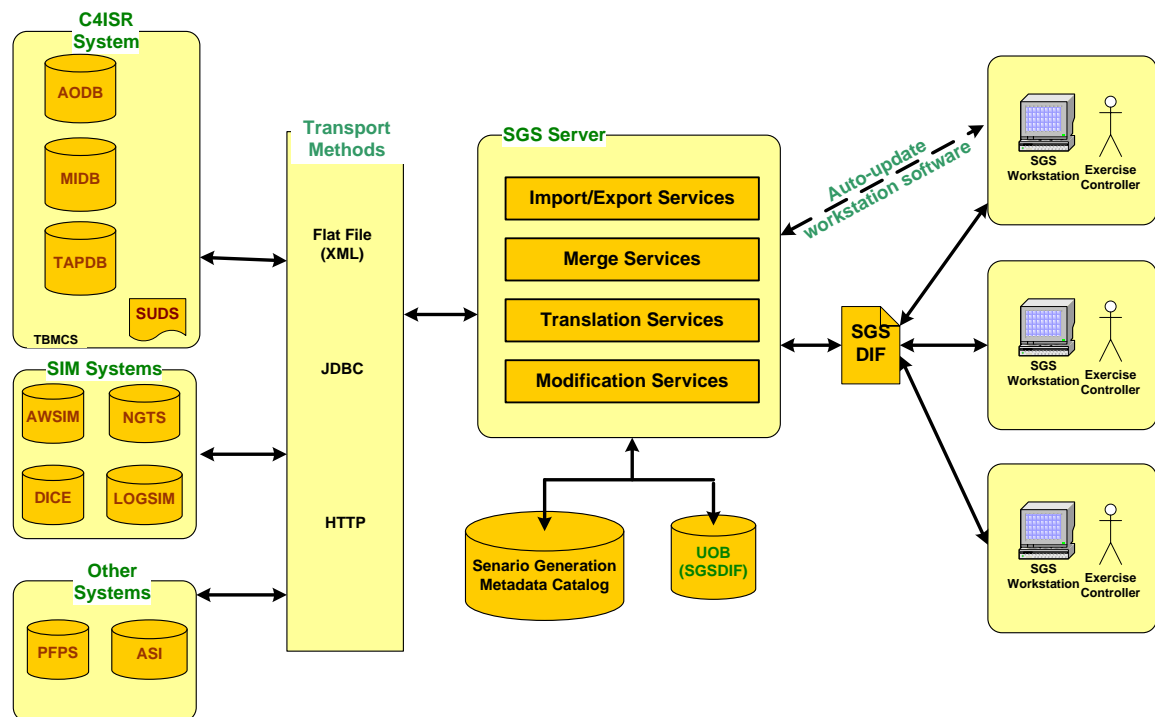


Figure 4: Scenario Generation Server (SGS) Architecture (Szych, 2003)

SGS does not distinguish between source and target. This enables reuse of any integrated scenario source, such as a threat scenario can be used in an AWSIM based exercise, and support of iterative development of scenarios. This means a scenario can be prepared and exported to the target systems, a target system operator makes a change, SGS can re-import from that target system, merge, and export (Szych, 2003).



### **2.2.2 Army C4ISR and Simulation Initialization System (AC SIS)**

The operational Army relies on the interoperability of numerous C2 systems which are in turn heavily dependent on data and associated databases. While many of these systems have unique databases, all are dependent to a high degree on common, interoperable data describing the battlefield environment, the tactical network, and the forces deployed. Prior to 2002 the process to develop the initialization data for Army Battle Command Systems (ABCS) and Force Battle Command Brigade and Below (FBCB2) was both time consuming and prone to error. The process was a sequential effort that began with a graphical system architecture diagram manually transcribed into an FBCB2 database. That in turn was used to build the required ABCS address book and system data bases using primarily manual processes. Engineers quickly discovered they had no reliable source of integrated data with which to build the required data base products (Carleton, 2006; Shane, et. al, 2005).

In 2002, the Central Technical Support Facility (CTSF) at Fort Hood, Texas started developing the Repository of ABCS Data. This system was a database and set of tools developed by the Systems Engineering cell in the CTSF to initialize the primary databases from a single source. Realizing the value of initializing simulation and C2 systems from a common database the Simulation-to-C4I Interoperability (SIMCI) Overarching Integrated Product Team and the DoD Modeling and Simulation Coordination Office funded projects to leverage CTSF effort and provide a semi-automated initialization capability for simulations. In 2003, the Repository of ABCS Data system became the Army C2 & Simulation Initialization System (AC SIS), which

continues to be a collaborative effort with SIMCI, led by the Program Executive Office for Command, Control, and Communications Tactical (Carleton, 2006; Shane, et. al, 2005; Black and Sprinkle, 2006).

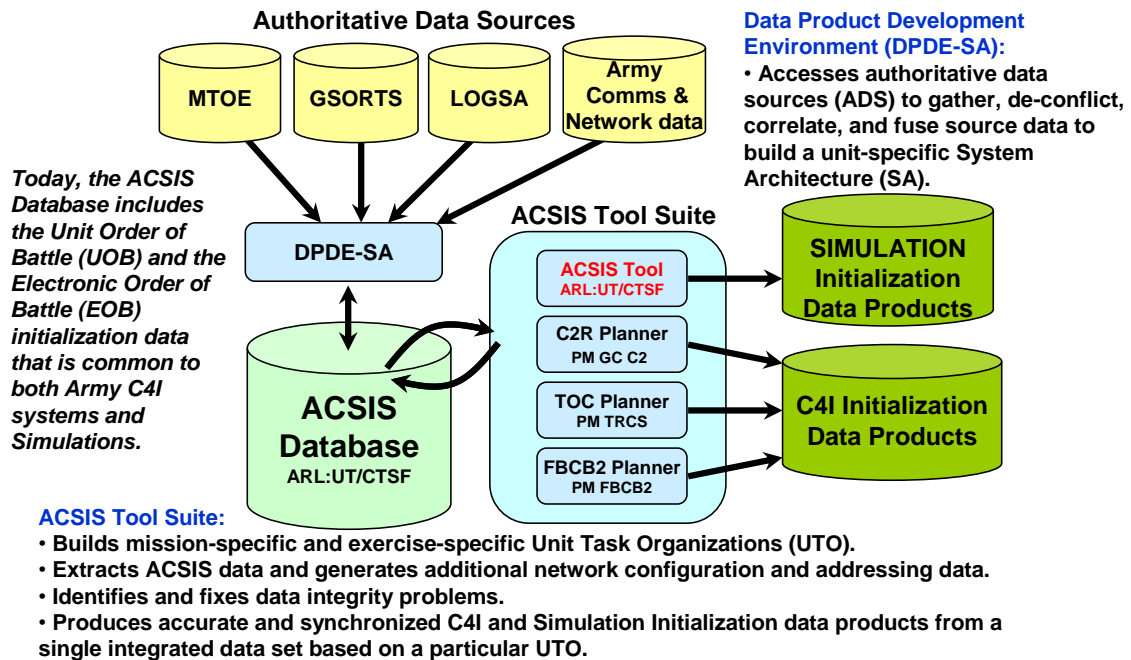


Figure 5: Army C4ISR Simulation and Initialization System (ACSIS) Architecture

From its inception, ACSIS has provided C2 initialization data products for the units deploying to Operations Enduring Freedom and Operations Iraqi Freedom, and some proof of principle simulation initialization data products to support mission readiness exercises. ACSIS, coupled with work by its customers and suppliers, has reduced the time required to define, de-conflict, and generate the initialization data products from well over 20 weeks to about 12 weeks. This is accomplished only after delivery of a unit systems architecture. The construction of the architecture is itself a laborious and lengthy process which takes several months. However, once an initial unit

task organization is built by ACSIS, variations of the unit task organization can be created in minutes. As a result of the ACSIS process, the Army is vastly more confident in the final data product quality than had been previously possible, but the Army realizes this is not a combat solution (Carleton, 2006; Shane, et. al, 2005).

Below is a brief description of each category of ACSIS-provided data, as well as a discussion of entity-level data and considerations of how to scope data needs (Carleton, 2006; Shane, et. al, 2005).

- *Force Structure Data.* Force structure data is a unit hierarchy as described by unit name, unit identification code, unit equipment and unit billets. Although currently only U.S. Army force data, the category includes different side (opposing, coalition, and neutral) and domain (ground, air and sea) force structure data.
- *Network Structure Data.* Information required to support network initialization are unit name, role names, universal resource numbers for all pieces of digital equipment (radios, routers, switches, battle command systems, etc), internet protocol addresses, subnets, router configurations, multi-cast groups, and email addresses. Note that network data will change with the advent of new systems, greater dependence on satellite communications and a move to flatter, less hierarchal architecture.
- *Command and Control Data.* This data is required to support integration of M&S applications into battle command systems for course of action analysis, mission rehearsals, and mission monitoring and robotic control. This category

includes all operations data related to plans and orders with accompanying overlays, matrices and control measures. While the ACSIS data model can accommodate this data, it is not usually populated in the products provided to customer units.

- *Entity-Level Data.* Not all systems require the same level of fidelity. Generally battle command systems are only concerned with organizations and platforms that have battle command-related digital systems. They are not concerned with voice-only radio systems. Likewise, they are not interested in initialization for most weapons, nuclear, biological and chemical equipment, individual warfighters (billets), organizations below platoon level, and the relationships of organizations to billets to equipment. Many simulation systems are interested in entity-level data because it associates attributes and behaviors with organizations, platforms, and billets. Just the opposite is true for communications where network initialization requires greater data fidelity than most simulations require. Data fidelity must be a consideration in all four categories.

### **2.2.3 Joint Integrated Database Preparation System (JIDPS)**

JIDPS utilizes authoritative data to produce user defined scenario files. JIDPS supports training and exercises, analysis and experimentation, mission planning and rehearsals. JIDPS is a web enabled tool that allows simulation database builders to quickly produce simulation initialization files for either a federation or standalone simulations. The order of magnitude is to reduce months of preparation time to minutes

for user specified scenario builds, and to hours for user specified terrain builds. JIDPS supports training and exercises, analysis and experimentation, mission planning and rehearsals. JIDPS currently has approximately 95 users that include the combatant commands and services, the US Secret Service, and foreign users upon request. JIDPS supports the joint live, virtual and constructive, and joint multi-resolution model federations (JFCOM, 2007).

JIDPS utilizes authoritative data to produce user defined scenario files. The authoritative data to produce force initialization files is to the entity level and is correlated. The users are able to query the authoritative data, drag and drop desired data, edit the order the order of battle data, output retrieved order of battle data in a common XML file, and output the terrain data in simulation format (JFCOM, 2007).

A future requirement is to create a scenario development workspace and build both the terrain and force data within it. Other future enhancements include the creation of a target repository, an automated process for data owners to request updates to the database, enhanced meta-tagging of data elements, enhanced search capabilities, and an expansion of federates served (JFCOM, 2007).

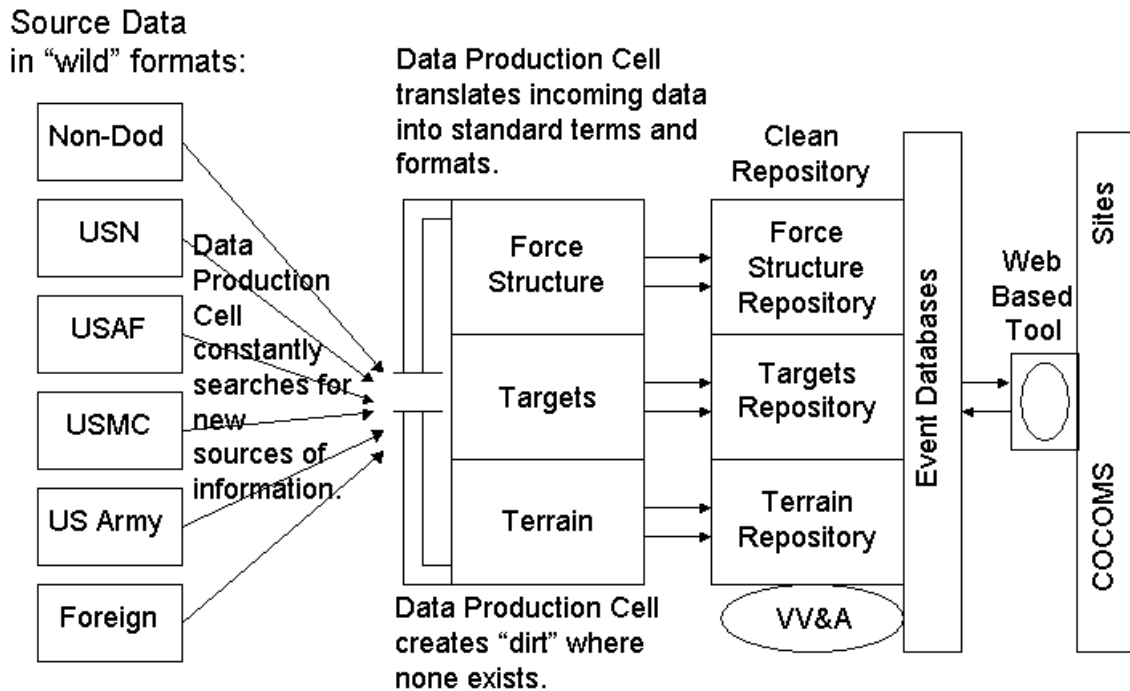


Figure 6: Unit Generation Utility (UGU) Data Flow Architecture

JIDPS is comprised of two components: The Terrain Preparation System and the Unit Generation Utility (UGU). JIDPS is a low cost program that develops and maintains the tools with a small footprint of approximately nine developers. The architecture is flexible to easily accommodate new functionality and data sources. JIDPS also has extensive user documentation and a help desk (JFCOM, 2007).

The UGU draws data from the Billet Level Standard Database. The output is a standard XML file which the simulations read in and convert to simulation specific formats. The UGU is object-oriented and programmed in Java. The user logs in and first either creates a new or opens an existing scenario. Next the user populates the scenario with sides, then drags and drops the units from the database repository into the scenario.

The user edits the scenario as needed, and then exports the scenario into an XML file. The initial version of the UGU was released in March 2007. UGU output is a standard XML file which the simulations read in and convert to simulation specific formats (i.e. JCATS).

The Order of Battle System (OBS), a next generation UGU, is a JFCOM Joint Warfighting Center built and owned simulation database production application that creates simulation-ready billet data (i.e., down to individual personnel) for JFCOM's Joint Live, Virtual and Constructive federation. The significance of the OBS is that what used to take months to generate simulation ingestible billet data is now reduced to hours when the appropriate source data is available. The OBS is able to do this because it is web enabled and allows users to produce from their home stations a basic, functional simulation database. This database can, with minor modifications, be used to support planning, operational rehearsals, and Joint, Service, or Agency training exercises (JFCOM, 2007).

#### **2.2.4 Unit Order Battle Data Access Tool (UOBDAT)**

The Unit Order of Battle Data Access Tool (UOBDAT) was developed by the Modeling and Simulation Coordination Office and consists of three main components: Unit Order Battle authoritative data sources (server); a Unit Order Battle data access tool (client) enabling scenario generation, task organization and resource allocation to include materiel holdings and personnel; and a Unit Order Battle data interchange format. Unit Order Battle sources are maintained by the owning organizations and made available to the UOBDAT in their native formats to the maximum extent possible. The data access

tool features a graphical interface that allows users to retrieve and browse unit order of battle data and associated information and select individual units easily in a common format and quickly across distributed networks. Figure 3 below represents UOBDAT's major components (MSCO, 1999).

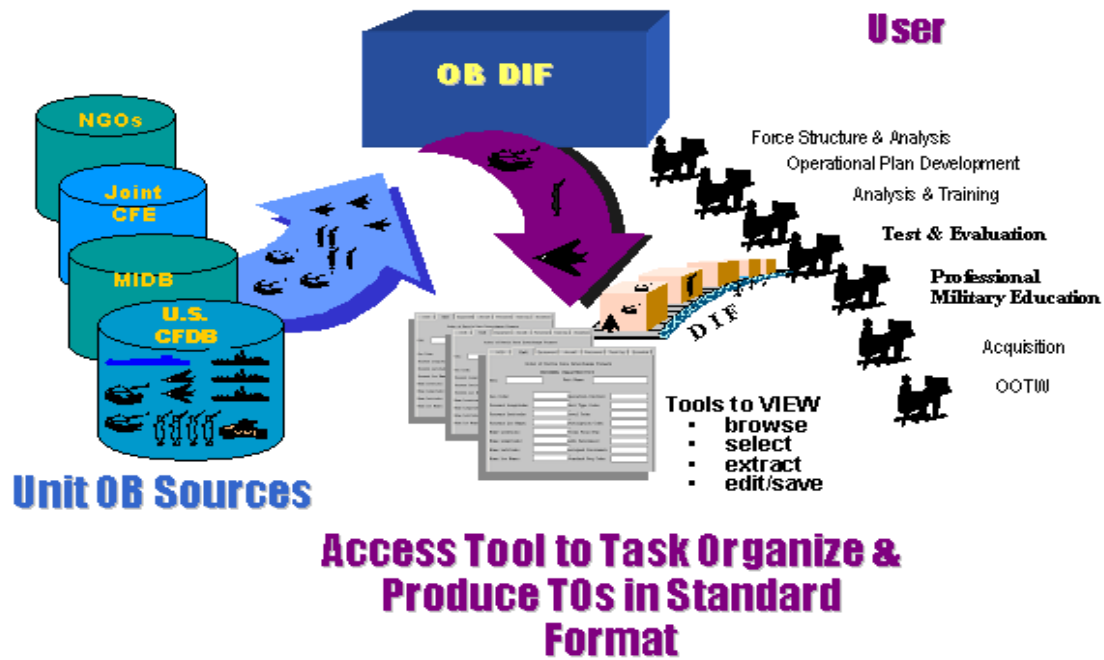


Figure 7: Unit Order Battle Data Access (UOBDA) Architecture (MSCO, 1999)

Currently the library of sources consists of classified and unclassified data for both friendly and foreign forces and reference data as well. Selected classified data include Defense Intelligence Agency's Modernized Integrated Data Base, the National Ground Intelligence Center's Joint Country Force Assessment threat data, Modeling and Simulation Coordination Office's Future Force Data Base to name a few. Examples of unclassified authoritative data sources include Service data, threat forces, Army transformation forces, entity level data and non-governmental organization data.



Reference data includes System Parametric Information Relational Intelligence Tool characteristics and performance data, Modernized Integrated Data Base target and facilities data and Global Command and Control System geographic reference file with world-wide locations data (MSCO, 1999).

The main purpose is to promote the rapid development of new scenario datasets by maintaining and publishing a re-usable library of existing scenario datasets and current authoritative data. JFDL is a broker for data; the data is maintained by the owners of the data, not JFDL (MSCO, 1999).

#### **2.2.5 Naval Aviation Simulation Master Plan (NASMP) Portable Source Initiative**

The NASMP initiated an effort in 2001 to standardize the methods by which databases are built and delivered. It is also planned to drive policy and contracting paradigms in this regard to acquire data that is both usable and useful to multiple training platforms across multiple services. NASMP Portable Source Initiative has put in place processes and procedures to (NAVAIR, 2007):

- define content development guidelines
- establish contracting policy for acquisition of databases
- develop archival capability for storing and distributing data, and
- establish configuration management policy for updating and enhancing existing datasets.

The goal of the initiative is to reduce duplication of costs by building visual and sensor databases using a variety of sources, feed all value-added work back into standard,

open, widely used source formats, and allow databases to be published from this "refined source data" in a relatively simple, automated, and repeatable fashion (NAVAIR, 2007).

### **2.2.6 Army Synthetic Environment (SE) Core**

SE Core is an acquisition program to meet the requirements of the Army-endorsed Operational Requirements Document. The SE CORE Operational Requirements Document is Joint certified and was approved by the Army in February 2005. SE Core supports the training of warfighters by providing (PEOSTRI, 2007):

- Development of a Standard Rapid Terrain Database Generation Capability utilizing a non-proprietary, open format, image generator independent, Master Terrain Database.
- Development of Common Virtual Components that will reduce redundancy, increase realism, and facilitate an integrated live, virtual, constructive training environment.
- One Semi-Automated Forces (OneSAF) Objective System integration into Close Combat Tactical Trainer and the development of virtual OneSAF composition as the standard computer generated forces for the virtual domain.

### **2.2.7 SOF Planning, Rehearsal, Execution Preparation (SOFPREP)**

SOFPREP is a U.S. Special Operations Command managed, centralized intelligence support activity. SOFPREP's government staff includes: Special Operations Command, Air Force Special Operations Command, National Geospatial-intelligence Agency civilians, Army, Air Force, and thirty seven support contractors. The SOFPREP

staff provides on-site technical and intelligence oversight to government and contractor personnel. SOFPREP provides Geospatial Intelligence source data support as well as other designated activities under the direction of U.S. Special Operations Command (DODSBIR, 2007).

SOFPREP's primary mission is to meet the Geospatial Intelligence data requirements of Special Operations Forces' Mission Training and Preparation Systems. SOFPREP's focus is Geospatial Intelligence digital source data and database production in support of U.S. Special Operations Command Mission Training and Preparation Systems Branch under the direction of Center for Knowledge and Futures Chief of Training (DODSBIR, 2007).

#### **2.2.8 Geospatial Intelligence Data Management (GIDM)**

Geospatial Intelligence Data Management (GIDM) System provides for spatial data manipulation, generation, 3-D visual development. GIDM organization consists of the SOFPREP facility as the centralized geospatial data management facility, the two database generation facilities that produce the common database, various other geospatial intelligence data producers and the geospatial data collection systems. The SOFPREP facility is staffed with government military, civilians and contract personnel with the responsibilities to collect, produce, archive, maintain and disseminate geospatial intelligence data that supports the command's mission planning, preview, training, rehearsal and execution systems. The database production facility produces common geospatial databases that support the visual, sensor and constructive display systems that are utilized in the command's mission planning, preview, training and rehearsal systems.

SOFPREP has the responsibility to maintain intelligence databases that are used to produce threat modeling systems and target facility models (DODSBIR, 2007).

SOFPREP also conducts verification and validation of the databases by performing geospatial accuracy and intelligence data integrity checks. SOFPREP interfaces with other organizations that produce geospatial intelligence data to collect, archive, and maintain their data and serves as the command's one-stop shopping warehouse for geospatial intelligence data supporting mission planning, preview, training, rehearsal and execution systems. With the development of more robust tactical collection systems the future will allow the rapid update of the geospatial intelligence data and databases. With the fielding of the new simulators there is also an effort to improve the common database, this will reduce correlation errors, increase interoperability and serve to improve the database delivery time by eliminating the requirement to publish to legacy database formats currently in use in the commands mission training, planning, preview and rehearsal systems (DODSBIR, 2006).

### **2.2.9 Environmental Scenario Generator (ESG)**

The Environmental Scenario Generator (ESG) is a web-based tool to generate realistic, authoritative environmental scenarios for models and simulations. ESG searches historical/modeled environmental (i.e., atmosphere, space, ocean, and terrain) databases to find customer-desired circumstances or events then processes the data to create an output composed of user-selected parameters in various standard formats (i.e., gridded binary, text, CSV, SEDRIS, and others specific to customer requirements). For example, atmospheric scenarios from ESG have been used in exercises Austere Challenge 2007,

Unified Engagement 2007 and Blue Flag 2007; Army Special Operations Aviation Training and Rehearsal Systems helicopter simulator, Joint Analysis System, and Joint Strike Fighter; and other M&S activities and models (Kihn, et. al, 2004).

The Air Force Combat Climatology Center hosts ESG and provides the subject matter expertise for generating atmospheric and space representations. The Department of the Navy assumes responsibility for ocean data. The National Geospatial-Intelligence Agency takes on the lead for terrain data. Although ESG functions independently of domain, it's predominantly used for atmospheric data at the present time. However, efforts are underway to expand the use of ESG for space and ocean scenarios (Kihn, et. al, 2004).

ESG undergoes continuous improvement. One ongoing project, Environmental Data Cube, will develop a comprehensive interface to create and deliver products consistent across a federation. Products will include basic environmental data, weather effects data, and synthetic images. The same project will also provide a distribution system to increase realism in exercise runtime and sequencing. Another project seeks to improve ESG functionality by adding search feature, increasing performance, and increasing customization of output. This should reduce reliance on and intervention by subject matter experts (Kihn, et. al, 2004).

The ESG is funded by the Modeling and Simulation Coordination Office and overseen by the Air Force Climatological Comand Center. It consists of 20 servers, a 55TB Storage Area Network, and a tape backup system (Kihn, et. al, 2004).

Data Sources: Atmospheric data includes 53 years of National Oceanic & Atmospheric Administration, National Centers for Environmental Prediction / National Center for Atmospheric Research Reanalysis and 10-year regional Advanced Climate Modeling and Environmental Simulation processed Meso-scale Atmospheric Simulation System model data at greater fidelity. The system can create other data sets to meet unique customer requirements. In the future, ESG will also be able to use data sets generated by the following models: Weather Research and Forecasting, Meso-scale Meteorological Model, Version 5, and Coupled Ocean/Atmosphere Meso-scale Prediction System (Kihn, et. al, 2004).

Space data comes from the National Geophysical Data Center in the form of Space Weather Global Derived and Observed Indices. One ongoing project will provide a tool to generate space data sets based on customer-desired effects. Current ocean data includes Wave Watch III Global Database and the Modular Ocean Data Assimilation System Global 2D and 3D Archives (Kihn, et. al, 2004).

#### **2.2.10 Joint Event Data Initialization Services (JEDIS)**

The Joint Event Data Initialization Services (JEDIS) project was sponsored by Joint Rapid Scenario Generation (JRSG), and developed by the Virginia Modeling and Simulation Center, and Gestalt LLC. JEDIS provides a common interchange model for four data initialization systems to integrate data from a common repository based on the JC3IEDM. JEDIS provides a set of web services that allow access to integrated joint event data sets for use in select federations. Also, JEDIS provides a SOA-based implementation of data initialization services for simulation and C2 federations.

Furthermore, run-time governance is established in JEDIS based on MBDE methods (Tolk, 2005; Tolk, 2008), JC3IEDM common reference model, and ISO/IEC 1179 standard. Design-time governance will need to be established upon creating additional data services that will interoperate with JEDIS in a federation (Tolk, et al., 2007).

### **2.2.11 Strengths of Current and Near-Term Solutions**

There exists many advantages of the current and near-term solutions described earlier:

- Each solution is a feasible attempt for the various DoD services to begin thinking about, designing, implementing, and testing authoritative common data sources,
- Each solution has its own unique advantages to solving “pieces” of the overall common data initialization problem,
- Many of the current and near-term solutions are often available for use in a simulation exercise,
- Provides common initialization data products (mainly files).

### **2.2.12 Weaknesses of Current and Near-Term Solutions**

Many of the disadvantages of the current and near-term solutions include:

- Accessing the various authoritative data sources is difficult and time consuming using conventional distributed client-server and file-sharing methodologies,
- Many of the solutions do not offer reusable tools or services for initializing common data within a simulation and C2 federation,

- There is no common solution for the dependability, consistency, verification, or validation of common data,
- There is little governance in the military simulation and C2 federation common data initialization service and process development.

## **2.3 Long-Term Solution**

There is a long-term strategy using a service oriented framework for the distribution of common initialization data. The following section describes a system that provides integrated common data and tools for federations.

### **2.3.1 Objective Initialization Capability (OIC)**

In 2004, the Army started the Objective Initialization Capability (OIC) program. OIC's primary goal is the development of a warfighter network initialization tool (Carleton, 2006).



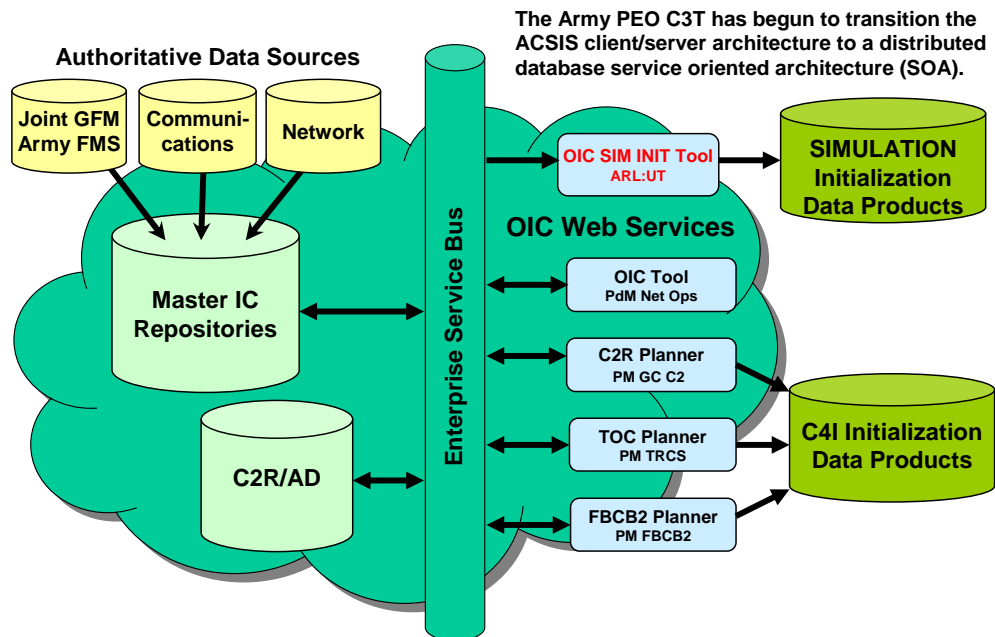


Figure 8: Army Objective Initialization Capability (OIC) Architecture (Carleton, 2006)

OIC will move the current ACSIS program to a web-based enterprise environment, compatible with the Army Knowledge Online Single Sign On initiative to build web enabled data products. It will use an SOA, an Army enterprise service bus, and a master initialization capability repository (Carleton, 2006).

### 2.3.2 Strengths of Long-Term Solution

There exists many advantages of the long-term solution:

- It is an initial look at using service oriented architectures to solve the common data initialization problem,
- It provides a common framework for authoritative data sources, applications, and services,

- Although, a long-term solution, it is currently funded and in the research and development phases.

### **2.3.3 Weaknesses of Long-Term Solution**

Many of the disadvantages of the long-term solution include:

- Currently only an Army-focused solution,
- Still does not provide an automated process for joint federation initialization,
- There is no common solution for the dependability, consistency, verification, or validation of common initialization data,
- There is no mention of governance or policy in which to provide some level of system and data manageability.

## **2.4 Alternative Approaches**

Although not in the scope of this research, it is worth mentioning some alternative approaches to consider in future research.

### **2.4.1 Software Agents**

One alternative approach may include incorporating software or intelligent agents as “services” into the SOA of a military simulation and C2 federation system. A software agent “is a piece of software that acts for a user or other program in a relationship of agency” (Hyacinth, 1996). Some examples of agent types that could be implemented specifically for this research area may include:

- heterogeneous (distributed) agents – these agents are designed to be very loosely coupled and can be executed as independent threads and on distributed processors (Hyacinth, 1996).
- data mining agents – these agents use information technology to find trends and patterns in an abundance of information from many different sources (Hyacinth, 1996).

Perhaps an integration of these software agents with SOA-based web and data services can provide a cutting edge, state-of-the-art technique for developing a federated simulation system with advanced interoperability and dynamic governance.

#### **2.4.2 Virtualization**

Another alternative approach is to incorporate *virtualization* technology.

Virtualization is defined as:

*"A technique for hiding the physical characteristics of computing resources from the way in which other systems, applications, or end users interact with those resources. This includes making a single physical resource (such as a server, an operating system, an application, or storage device) appear to function as multiple logical resources; or it can include making multiple physical resources (such as storage devices or servers) appear as a single logical resource." (Mann, 2008)*

IBM has been conducting research and implementing prototypes that introduce virtualization techniques to enhance SOA-based systems. IBM explains that a big part of services and composite applications is their mobility and dynamic nature. It

certainly would be painful to manually administer and manage their life cycle across a distributed infrastructure. So, the ability to start and stop services, schedule composite applications, and place both of them for execution is a primary benefit of workload virtualization and products such as IBM's WebSphere® Extended Deployment (IBM, 2008).

Furthermore, IBM notes that workload virtualization is not only scheduling but the coordination of scheduling, workload management, and provisioning. Workload virtualization allows services to be started where needed and when necessary. If workload requests increase, additional services (clones) can be started automatically on additional resources, and work can be routed to them. If either a service or the resource it is running on fails, the same auto-start and workload rerouting can be achieved. This approach is sometimes referred to as service virtualization, where interactions between service providers and service consumers are through an abstraction layer (in this case, what we refer to as workload virtualization provides this layer). As the size and scale of SOA deployments grow, service virtualization will become increasingly important. In addition, intelligent scheduling techniques can split apart a composite application or workflow and parcel out the work for execution across a heterogeneous, distributed pool of resources (also known as a grid) (IBM, 2008).

### **2.4.3 Semantic Web Services**

The mainstream XML standards for interoperation of web services specify only syntactic interoperability, not the semantic meaning of messages. For example, the

Web Services Description Language (WSDL) can specify the operations available through a web service and the structure of data sent and received but cannot specify semantic meaning of the data or semantic constraints on the data. This requires programmers to reach specific agreements on the interaction of web services and makes automatic web service composition difficult. Semantic web services are built around universal standards for the interchange of semantic data (Zeng, 2001), which makes it easy for programmers to combine data from different sources and services without losing meaning. Web services can be activated "behind the scenes" when a web browser makes a request to a web server, which then uses various web services to construct a more sophisticated reply than it would have been able to do on its own. Semantic web services can also be used by automatic programs that run without any connection to a web browser (Zeng, 2001).

#### **2.4.4 Non Defense SOA Governance Communities**

While formal governance is immature in SOA-based data initialization of military simulation and C2 federations, there are many examples of non-defense related research and products that promote and implement rigorous SOA governance techniques. Organizations such as IBM (IBM, 2006), Hewlett Packard (Hewlett Packard, 2008), Oracle (Oracle, 2008), AgilePath (AgilePath, 2006), LogicLibrary (LogicLibrary, 2008), Gartner (Gartner, 2007), and ZapThink (ZapThink, 2006) are just a few that offer well-defined SOA governance reference products and frameworks. Although many of the aforementioned organizations are commercial and provide mainly proprietary solutions, there are open-source organizations that offer resources. OASIS defined a generic SOA

governance reference model that can be customized to fit any organization's needs (OASIS, 2004). Furthermore, WS02 (WS02, 2009) offers a fully open-source SOA platform with service registry infrastructure that can be downloaded and configured to specification. Thus, there are many documented case studies whereby best practices can be extracted and applied to a governance reference model for data initialization services in a SOA-based simulation and C2 federation.

## **2.5 SOA Governance Organizational Best Practices**

Best practices suggest that successful SOA and data service implementations most often take place within the context of an organizational commitment to operate more efficiently and effectively. Thus, to ensure a successful application of SOA to the organization, this dissertation will address SOA within DoD from an organizational perspective.

To address SOA in this manner, "organizations" of interest for DoD were identified. An enterprise implementation of SOA strategies and data service deployments requires extraordinary levels of commitment and organizational "horsepower" to affect enterprise-level changes, consistency, and governance. The DoD will be attempting to consolidate SOA, web service solutions, and consistent governance throughout what amounts to an enterprise of already established enterprises. By comparison, industry and individual companies have better control over their smaller individual enterprises and can better affect change and consistency. The review of organizational best practices is divided into categories:

- Vision and Leadership

- Policy and Security
- Strategy and Roadmap Development
- Acquisition and Behavior
- Implementation and Operations

Each category is examined in detail. Since most of the topics are broader than specific cases, only certain categories address specific industry cases.

### **2.5.1 Vision and Leadership**

The decision to implement SOA in an organization requires an extraordinary commitment from senior leadership. Senior leaders must articulate the vision for the effectiveness desired from a web-based approach to information sharing as well as the value of moving beyond simple process automation to the ability to rigorously answer key business questions in real time (IBM, 2006). More importantly, leaders must anticipate and aggressively attack cultural resistance to the availability and sharing of information throughout their enterprise, and promote the value that consolidation and self-service enablement brings. This requires clear, consistent evangelizing and messaging (webMethods, 2006). Best practices in this area include:

- Evangelize the benefits of net-centricity, SOA, web services, and transformation (NAVAIR, 2007; DODCIO, 2006).
- Actively manage the cultural, strategic, and tactical issues of a major paradigm shift (BEA, 2007).
- Proactively address the cross domain and cross business area issues.

- Team with industry, across military services, and across executive agencies (IBM, 2006; AT&T, 2004).
- Create and document a business case for SOA (AgilePath, 2006).

### **2.5.2 Policy and Security**

Once leaders have made the decision to improve business and doctrinal/tactical processes using web services, best practices requires the careful development of an architecture for and taxonomy of those services. The chosen services need to align well within the range and scope of operational architectures that the enterprise envisions supporting. Further, leadership must make decisions about the general standards models and ontologies that will be implemented across the enterprise and within communities of interest (OASIS, 2006). This addresses one of the key issues with SOA—ways to deal with the inherent diversity of representation of the battle space or business landscape in information systems on the network. In addition, leaders need to consider the acquisition model for building such services and incentivizing (or indemnifying) interdependence of systems and services (OpenGroup, 2009). Finally, senior leaders must carefully determine the organization's approach to security policies and risk mitigation, items that they then must craft into policy guidance. A blend of a modest amount of top-down direction in key areas, particularly security and acquisition policy, combined with a healthy dose of bottom-up creativity and initiative appears to be the most effective practice (IBM, 2006). Best practices in this area include:

- Establish technical standards (OASIS, 2006; webMethods, 2006; Sun Microsystems, 2006; Gartner, 2007; AgilePath, 2006).



- Establish portfolio management policies and policy/information standards and put them in a standards-based registry (OpenGroup, 2009; BEA, 2007; Oracle, 2008; AgilePath, 2006).
- Establish application interoperability policy (OpenGroup, 2009; AgilePath, 2006).
- Consider how to benefit from both top-down and bottom-up leadership (IBM, 2006; AT&T, 2004).
- Establish governance, security, reuse, compliance, risk management, and versioning policies (Gartner, 2007; OASIS, 2006; AgilePath, 2006).
- Employ multiple security approaches (Microsoft, 2008; ZapThink, 2006).
- Ensure security is “baked into the solution.” (ZapThink, 2006; Oracle, 2008).
- Address SOA-unique security considerations (Microsoft, 2008; ZapThink, 2006; Sun Microsystems, 2006).
- Plan for disaster recovery, business continuance, and disaster management (IBM, 2006; Hewlett Packard, 2008).

### **2.5.3 Strategy and Roadmap Development**

A strategy and implementation roadmap captures the details of the execution of a web-based information sharing and optimization structure. Included in the roadmap are the architectural, structural and definitional details specific to the enterprise, as well as security and risk management considerations. SOA best practices mandate that this key

step, the roadmap, evolves concurrently with policy, acquisition and behavior. Additionally, best practices suggest that the roadmap is often influenced more by the adoption of a variety of minor implementations, experiments, and demonstrations across the organization than by explicit leadership direction. Best practices in this area include:

- Develop, document and publish SOA strategy (Gartner, 2007).
- Plan for incremental transformation and deployment (IBM, 2006).
- Align programs/projects to share services (Hewlett Packard, 2008; OpenGroup, 2009).
- Maintain a vision of shared services but move toward it opportunistically and incrementally (Hewlett Packard, 2008).
- Design for connections, change, and control (Oracle, 2008).
- Create a common vocabulary (BEA, 2007; webMethods, 2006).
- Recognize the importance of cross-enterprise architecture (Microsoft, 2008; AgilePath, 2006; Hewlett Packard, 2008).
- Define and enforce application interoperability and business interoperability policies (IBM, 2006; AT&T, 2006; Oracle, 2008).

#### **2.5.4 Acquisition and Behavior**

Acquisition and behavior are two very different yet related processes. The best practices analysis revealed that proven processes that work well for the acquisition of standalone systems are not sufficiently agile to keep up with the evolution of both technology and broadly accepted standards and processes for SOA. Instead, market-

driven models that embrace frequent change, strong involvement with industry and standards bodies, and close ties with internal and external user communities are the most effective acquisition models for SOA.

Governance processes must be similarly adaptive and flexible; what the enterprise needs, what systems the enterprise will build, and how those systems will be built will be much different tomorrow than they are today. Of course, the enterprise must also stay within fiscal constraints. Organizations must have discipline and rigor in the enforcement of the architectures, standards, and policies they adopt for SOA because without rigorous governance, the organization will not realize SOA's potential benefits.

Gartner cautions, "Service-oriented architecture built opportunistically with the purpose of "getting it over with" as soon as possible, and at as low a cost as possible, will prove to be a disaster for enterprises' software infrastructures" (Gartner, 2007). Accordingly, simplicity, interoperability based on open standards, scalability, and loosely coupled, modular services are keys to an effective governance process in the organization's dynamic environment. Best practices in this area include:

- Incremental acquisition (Oracle, 2008).
- Use experiments, pilots, and collaborative demos (AT&T, 2004).
- Consider using enterprise modeling (Hewlett Packard, 2008; BEA, 2007).
- Enforce policies (webMethods, 2006; ZapThink, 2006).
- Loosely coupled services require detailed governance, management, and Service Level Agreements (OpenGroup, 2009; Sun Microsystems, 2006).

- Monitor, measure, and analyze the enterprise's SOA service network (OASIS, 2006; Gartner, 2007).
- Promote Service Discovery and governance using a standards-based registry (ZapThink, 2006).
- Consider run-time discovery where appropriate and where it provides business value (Oracle, 2008).
- Promote standards based process models, such as Business Process Execution Language or Unified Modeling Language, for process model interoperability (IBM, 2006; Oracle, 2008; Microsoft, 2008)..

### **2.5.5 Implementation and Operations**

This is where the “rubber meets the road” for SOA. Best practices reinforce that effective web services and SOA are implemented incrementally, but rapidly—building and testing each step and then formally “cutting in” the service and moving on to add the next. Hesitation and skepticism typically occurs as services and SOA are implemented, and, in many cases, employees and customers experience a slight dip in the quality of services before the quality recovers and rapidly improves. Leadership is key, as ongoing operations demonstrate the worth of web services and SOA—increased organizational effectiveness with radically improved access to information and collaboration, reduced costs with reusable assets, reduced personnel requirements, and improved customer satisfaction and employee morale. Best practices in this area include:

- Implement incrementally following the delivery of business value (benefits) (OpenGroup, 2009; BEA, 2007).
- Partnering and collaborative implementations work best (Oracle, 2008; Gartner, 2007).
- Implementation is more important than theory (AgilePath, 2006; Hewlett Packard, 2008).
- Ensure a robust publishing and discovery model to facilitate sharing and reuse (Gartner, 2007; ZapThink, 2006; IBM, 2006; Oracle, 2008).

The concept of SOA governance is not new and many organizations have developed SOA-based solutions in attempt to standardize governance activities in an SOA-based environment. However, many of the solutions are proprietary and require specific implementations. The governance reference model presented in this dissertation proposes to provide a reference model that is open-source, and implementation and platform independent.

## **2.6 Formats and Standards**

In 2004 the ACSIS team developed a Data Product Integration Plan. Even though the primarily focus was only data needed to support network initialization, the team identified multiple instances of 10 different media formats (e.g. xls, sql, pdf) across seven types of field formats (e.g. db, NetViz, flat file) (Carleton, 2006), (Shane, et al., 2005). These multiple format identifications coupled with the results of the ACSIS team study represent an area ripe for standardization. Standardization efforts will be discussed next.

In the context of relative importance and use, three emerging standards are discussed below:

- Command and Control Information Exchange Data Model (C2IEDM)
- Joint Command, Control and Consultation Information Exchange Data Model (JC3IEDM),
- Mission Scenario Definition Language (MSDL), and
- Battle Management Language (BML).

In September 2005, the Army endorsed use of the C2IEDM as the standard for Battle Command systems information exchange. In June 2006, the Army issued additional guidance on migration to the JC3IEDM (Tolk, 2006). Use of the new standard is mandatory for emerging systems to include Future Combat System and Distributed Common Ground Systems-Army. Legacy systems and systems currently under development including the Objective Initialization Capability will support exchange of data in the C2IEDM/JC3IEDM format (Carleton, 2006; Tolk, 2006). XML schemas for both C2IEDM and JC3IEDM will be maintained in a DoD registry. The Army will ensure existing battle command systems, and M&S interfaces comply with existing C2IEDM/JC3IEDM standards.

The Army's Objective One Semi-Automated Forces (OneSAF) program and various members of the Army and Joint Services community has developed the Military Scenario Definition Language (MSDL) (MSDL, 2006). MSDL intends to serve the international command and control and simulation domains with data representation and file transmittal format standards to define military scenario information that can be

populated by MSDL-compliant scenario planning tools, including command and control planning applications, and read by MSDL-compliant live, virtual, and constructive simulations, including DIS or HLA-based federations (MSDL, 2006), (Henninger, 2003). In 2004, the Simulation Interoperability Standards Organization (SISO) approved OOS' petition to establish an MSDL study group to verify the need for standardization, evaluate existing related standardization efforts, and cultivate a broad base of support across the simulation community for development of an MSDL-based standard (MSDL, 2006). In 2005, SISO approved establishing a product development group to develop a coalition MSDL standard. MSDL is defined using an XML schema to enable exchange of all or parts of scenarios (MSDL, 2006).

In 2001 the Simulation to C2 Interoperability (SIMCI) Organizational Integrated Product Team initiated the Battle Management Language (BML) project. BML's underlying concept is to enable direct communications between BC systems and simulations. BML's goal is to enable automatic and rapid unambiguous tasking and reporting between C2 and M&S systems (Tolk, et al., 2004). Like MSDL, a Coalition Battle Management Language (CBML) is also moving towards standardization under SISO. The U.S. version of BML uses C2IEDM as the underlying data model and has had several proof-of-principles using an XML version, XBML. SIMCI continues to fund selected BML projects focused on identifying required extensions needed in C2IEDM for BML and integration of BML in ACSIS (Tolk, et. al; 2004; MSDL, 2006; Henninger, 2003; Carleton, 2006; Shane, et al., 2006).

The emergence of these two new standards, MSDDL for simulation initialization and BML for battle command and simulation initialization, both using JC3IEDM data exchange, provides an opportunity for the initialization community to move towards standardized initialization formats for battle command and simulations. Adoption of these standards would reduce development and sustainment costs not only for initialization tools but for battle command and simulation systems as well (MSDDL, 2006).

## **2.7 Argument for a Governance Reference Model**

A reference model is an abstract representation of something that embodies the basic goal or idea of something and can then be looked at as a reference for various purposes (OASIS, 2006). It is necessary for the governance committee to have a reference model that is consistently applied to the entities to be governed. The idea of an SOA governance reference model was initially proposed by Norbert Bieberstein as an entity-relationship diagram (Bieberstein, 2007). He explains that the model has been successfully used in various governance consulting assignments.

Figure 9 below is a proposed variation of the diagram (Bieberstein, 2007) that conceptually illustrates the components that make up a proposed governance reference model for data services in simulation federations. The initial conceptual governance reference model includes:

- Policies and Standards to enforce
- Processes and Procedures to implement
- Roles and Responsibilities to manage
- Metrics to monitor the data service lifecycle



- Behaviors to motivate and sustain the process

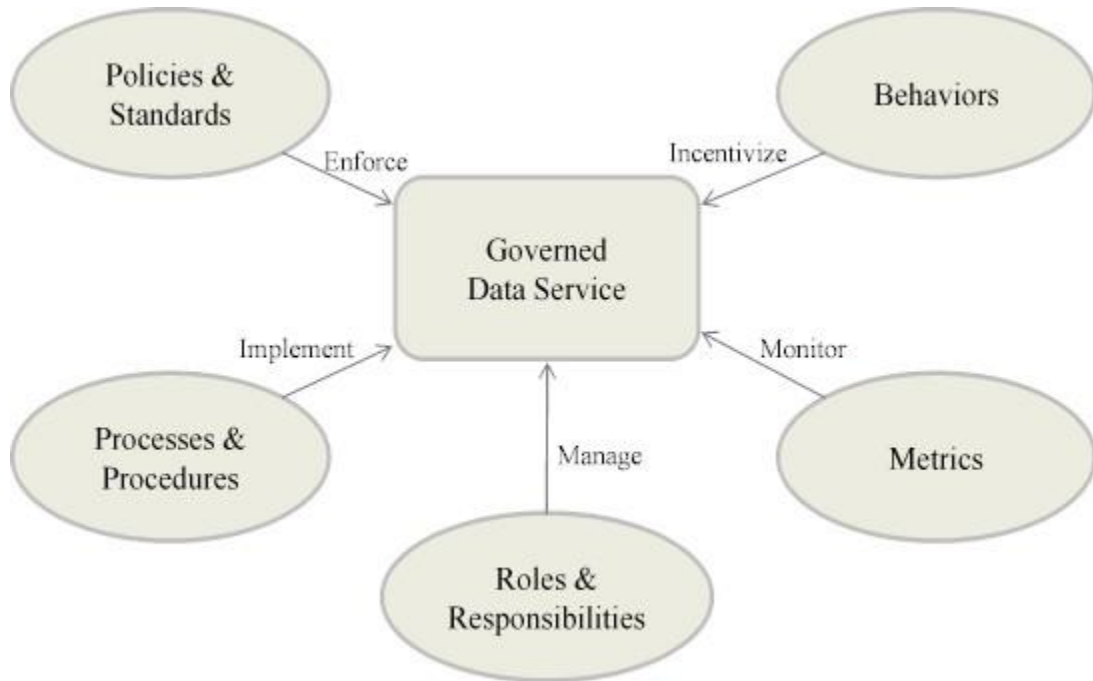


Figure 9: Initial Conceptual Governance Reference Model for Data Services

The details of the initial conceptual governance reference model will be modified and extended into a full governance reference model in the succeeding chapters.

### 2.7.1 Description of a New Strategy

SOA has been identified as an enabler for Net-Centricity (Mills, 2007). It has proven itself as a viable approach to achieving services reuse, application integration and business agility while delivering compelling financial benefits (Erl, 2007). SOA enables intrinsic interoperability through the use of standards-based reusable services. In addition,

SOA enables greater leverage of existing legacy systems by exposing existing functionality using defined interfaces (Erl, 2007; Linthicum, 2003; Vietmeyer, 2005).

Dr. Andreas Tolk states that, “The use of distributed M&S applications to support the warfighter is an established requirement.” He explains that current systems are “interface-driven” and “point-to-point” solutions with “limited potential for reuse”. Dr. Tolk continues to describe how an SOA and associated M&S common data services could provide a feasible solution for a “common heterogeneous information infrastructure” for future Net Centric Warfare applications. M&S common data services may also provide a gateway for migration of legacy M&S software applications into the future Global Information Grid (Tolk 2006).

SOA-based solutions for data initialization in simulation and C2 federations are the new strategy for joint data services development and reuse (Carlton, 2004; Black, 2006; Hieb, 1999; Gustavsson, 2004; Volker, 2006). However, implementation of an SOA would require creating a governance reference model from the ground up, incorporating the best practices of current solutions described earlier, that would have the ability to meet the goals and constraints of the various federations. The governance reference model would provide a generic, common platform for the data initialization of federation simulations and command and control systems. Specifically, a governance reference model will potentially:

- provide a common reference to promote reusable data services that initialize common data products from various authoritative data sources,

- support reusable policies, standards, and processes across varying simulations and inter-service domains,
- provide greater common data consistency, verification, validation, and re-use,
- allow sharing of common data assets,
- provide easier common data migration & change management, and
- provide improved definition of policies and agreements for common data assets across the SOA environment.

### **2.7.2 Solution to a Previous Weakness**

A governance reference model in developing SOA-based data initialization services for joint military federation simulation and C2 systems would address many of the weaknesses to previous SOA-based strategies. It has the potential to allow full interoperability of common initialization data and tools across a federation. While there would be an initial implementation cost, the reference model would have a low lifetime cost because of the savings gained from faster data service development, faster initialization of common data and interoperability, and reusable policies, services, processes, and policies. Because the governance reference model will have been created to address common data services for joint military training objectives, it could be used as a framework across all DoD organizations and their respective simulation systems. This could be done without the re-engineering effort currently required to initialize common data from one military service to the other. Furthermore, a governance reference model

will further allow SOA-based solutions to satisfy the DoD requirement for systems to meet the Net-centric Enterprise Service objective (Vietmeyer, 2005).

### **3.0 RESEARCH CONCEPT AND METHODOLOGY**

This chapter presents a methodology for the research that will be accomplished. It first summarizes the research concept and research goals and then outlines a four phase approach for developing and testing the SOA-based governance reference model. Phase I is an analysis phase which uses stakeholder input (structured interviews) to identify risks and issues which the governance reference model will have to address. Phase II presents a formal process for the design and documentation of the governance reference model using strategies based on factors and issues derived in Phase I. In Phase III, an implementation of the governance reference model will be completed through the development of a SOA governance and data service prototype application based on stakeholder requirements and best practices defined in Phase I and design strategies in Phase II. An application-oriented evaluation of the governance reference model and prototype developed in Phase III will be carried out in Phase IV using a test plan and the Goal-Question-Metric approach to verify that the governance reference model exhibits the characteristics required to meet its objectives. Finally a summary of the original contributions made by this research will be given.

#### **3.1 Research Concept**

This research attempts to systematically develop, document, and evaluate an SOA-based governance reference model for use in the design, development, and sustainment of common data initialization services in military simulations and C2 federations. This research will be scoped by its focus on a single product line, or family,

of small-scale constructive simulations used for military training. Principles discovered in this research, if proven valid, should be able to be generalized to other larger-scale constructive simulation systems. The research will prioritize breadth over depth, for example it will attempt to address the policies required to support a wide variety of constructive simulations implemented for joint military use, but it will not provide a full decomposition of every policy. The research will emphasize the development of design decisions over the specification of design details. It will not attempt to fully describe every policy, procedure, standard, specification, protocol, metric, behavior, and common data element but it will address where future work is required and provide direction for that work.

Several goals have been set for this research. It will attempt to identify the priorities and goals of many of the stakeholders involved in SOA-based common data initialization of military simulation and C2 federation systems. It will identify the principal political and technical challenges faced in developing a governance reference model for these stakeholders. It will develop and document design strategies and best practices used in the creation of the governance reference model. Finally the research will provide a basis for future work in the areas of SOA-based governance, data service development, and common data initialization in military simulation and C2 federation systems.

### **3.2 Phase I: SOA Governance Global Analysis Methodology**

The purpose of an analysis phase prior to the development of a SOA-based governance reference model is to analyze the key factors and elements that influence the

governance reference model and to develop strategies for accommodating these key factors and elements in the reference model design. This is important because it provides a solid foundation from which to make modeling decisions which will lead to strategies that drive SOA-based service design and development.

The *Global Analysis* methodology is a problem-space factor analysis process developed by Hofmeister, Nord, and Soni (Hofmeister, 2000) in their book, *Applied Software Architecture*. This methodology typically used in software architectural analyses presents a process for analyzing various factors that could influence the architecture. However, as stated earlier, a governance reference model is an abstract representation of something that embodies the basic goal or idea of something and can then be looked at as a reference for various purposes (i.e. reference architecture) (OASIS, 2006). Thus, the factors can be abstracted to address a governance reference model which will be adapted for use in this research. In this research a set of structured interviews will be used to identify those factors. Factors will be analyzed in order to generate a set of issues that the reference model must address, and ultimately develop solutions and strategies that will define a fully extended governance reference model.

### **3.2.1 Structured Subject Matter Expert Interviews**

The success of this research depends on the precision, robustness, and clarity of stakeholder requirements. Structured interviews will be conducted with subject matter experts. These interviews are designed to help capture requirements and key factors on a variety of issues related to common data initialization, architectures, SOA, business

models, policies, processes, and standards for military simulation and C2 federation systems.

Nine subject matter experts in this domain will be interviewed. Their responses will be used to identify the key factors facing the proposed governance reference model. Questions will be formulated to highlight the most significant issues facing the reference model in its various domains. Interviews will be conducted by questionnaire via email or over the phone and, if needed, questions will be adapted on-the-fly to suit the information received from the expert. Responses will be recorded, or if possible, machine-recorded for later review. The following questions will be presented to the experts:

### **Service Oriented Architecture**

- *Question 1:* In the attached journal article<sup>1</sup>, Service-oriented Architecture (SOA) is defined by OASIS as: “A paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains...”. Dr. Thomas Erl defines SOA as: “An architectural model that aims to enhance the efficiency, agility and productivity of an enterprise by positioning services as the primary means through which solution logic is represented in support of the realization of strategic goals associated with Service Oriented Computing”. Lastly, J. Dorn defines SOA as: “A shift in the information system paradigm from document-centric transactions of business information to process-centric and service-based data exchange.”. Which definition is closest to your own

---

<sup>1</sup> Lanman, J.T., Proctor, M.D. (2009). “Governance of Data Initialization for Service Oriented Architecture-based Military Simulation and Command & Control Federations”. *Journal of Defense Modeling and Simulation: Application, Methodology, Technology*, Vol. 6, No. 1, 5-16 (2009), DOI: 10.1177/1548512909344525.



definition? If you feel that the current best definition is still inadequate, what would you rewrite in the current best SOA definition?

- *Question 2:* An InfoWorld study released in July 2006 (figure 2 above) determined that 42% of the SOA projects examined identified a lack of governance to be the largest factor inhibiting SOA adoption. Governance factors cited as being the most lacking that inhibited SOA adoption were: (1) Implementation of service processes and procedures, (2) Enforcement of service policies and standards, (3) Monitoring and evaluation of services using metrics, (4) Management of service and user roles and responsibilities, and (5) Incentivizing user behaviors. Is the list below of factors that inhibit SOA complete? If not, what is missing? Are any of these SOA inhibiting factors inhibiting your organization from either adopting or advancing SOA within your organization? To the extent of your knowledge please list in chronological order the SOA inhibiting factors that your organization has overcome. Can you estimate how long it took to overcome each SOA inhibiting factor in order to establish a baseline SOA? What SOA inhibiting factors is your organization currently working on? What SOA inhibiting factors does your organization plan to address or overcome during the next year in order to raise the SOA level in your organization?

### **Governance**

- *Question 3:* Mr. M. Josuttis stated in his textbook, *SOA In Practice: The Art of Distributed System Design*: “The goal of SOA governance is to develop processes

and oversight to ensure that services are developed and sustained to promote a flexible and dynamic infrastructure.” Further, a conceptual GOVERNANCE reference model as shown in figure 9 below has been proposed in the attached journal article<sup>1</sup>. In your mind, does figure 9 reflect all the key concerns that impact successful SOA Governance? What other activities and relationships (if any) should be included in the Conceptual Governance Reference Model? What activities and relationships should be removed or modified? Can you identify and describe any gaps in the Conceptual Governance Reference Model? For example, would you define Security within the context of the Conceptual Governance Reference Model below or prefer to propose a different Governance Reference Model?

### **SOA Governance**

- *Question 4:* Eric Marks and Michael Bell note in their book, *Service Oriented Architecture: A Planning and Implementation Guide for Business and Technology*, that there is a paradigm shift in an organizations’ business model in order to implement SOA and SOA governance. With this shift, there is a significant learning curve that directly affects initial and long term cost and schedule. Literature points out that the initial cost and schedule are high but reduce significantly as the organizational SOA enterprise matures. What do you perceive to be the most challenging business related obstacles to implementing, operating, or using an effective SOA governance reference model for your organization?

## **Business Model**

- *Question 5:* The attached article<sup>1</sup> describes related work in SOA governance and data exchange within government (i.e. MSDL standard, BML standard, Objective Initialization Capability), industry (i.e. IBM, Oracle, HP, ZapThink, etc.), and academic (i.e. JEDIS) organizations. However, due to variants within organizations, there is no single business model that promotes well-defined SOA governance. Examples of these invariants include the existing governance in place, the SOA maturity level (if applicable), size of the organization, etc. How would you begin to develop a business model that incorporates SOA and SOA governance for data exchange? Based on your ideal business model:
  - a) What decisions need to be made in an organization to have effective SOA governance?
  - b) Who should make these SOA governance decisions in an organization?
  - c) How will these SOA governance decisions be made and monitored in an organization?
  - d) What organization structures, processes, and tools should be deployed in an organization?
  - e) What metrics are required to ensure that an organization's SOA implementation meets their strategic goals?

## **General**

- *Question 6:* What additional advice and recommendations do you have for someone developing a SOA governance reference model for military simulation and C2 federation needs?

### **3.2.2 Key Factor Analysis**

Once the interviews have been completed, responses will be analyzed to produce the key factors. The *Global Analysis* methodology describes three steps involved in factor analysis (Hofmeister, Nord, and Soni, 2000):

#### *Step 1: Identify and describe the factors*

Consider and document the primary factors that have significant global influence, that could change over time, and that are difficult to satisfy.

#### *Step 2: Characterize factor flexibility and changeability*

Consider and document what is negotiable about the factor. The negotiating could be with any of the stakeholders (managers, marketing personnel, customers, users, etc.).

#### *Step 3: Analyze factor impact*

Consider and document areas of the reference model that are affected by the factor or changes to the factor.

After the three-step factor analysis, factors will then be assigned to one of three categories described below:

1. *Organizational Factors:* Organizational factors are factors related to schedule, budget, organizational attitudes, business models, policies, standards, and processes.

2. *Technological Factors*: Technological factors are factors related to hardware, software, architectural technologies, protocols, tools, and products available for use or reuse.
3. *Product Factors*: Product factors are factors related to functional features and qualities such as performance, dependability, reliability, adaptability, etc).

Factors will be documented in the following format:

Table 4: Factors Documentation Template

<No.>	
Name:	<Factor name>
Category:	<Factor category>
Description:	<Description of factor>
Flexibility and Changeability:	<What aspects of the factor are flexible or changeable?>
Impact:	<Elements affected by the factor or changes to it>
Reference:	<Trace reference to interviews and best practices>

### 3.2.3 Issue Documentation

Once the key factors have been identified, a set of issues derived from those factors will be documented. An issue is a single intricacy that arises based on a factor or set of factors and must be explicitly addressed by the governance reference model.

Issues will be documented in the following format:

Table 5: Issue Documentation Template

<No.>	
Name:	<Issue name>
Description:	<Description of issue>
Influencing Factor(s):	<The factor or list of factors that affect this issue>

This table will be expanded in phase II to include specific solutions and associated strategies that will address each issue.

### **3.3 Phase II: Design and Documentation Approach of Governance Reference Model**

In Phase II, strategies will be developed to drive the governance reference model design and documentation. The design and documentation will be specified using formal modeling notation. The formal design and documentation will drive the implementation of the prototype.

#### **3.3.1 Strategy Development**

For every issue identified in the analysis phase, a corresponding strategy will be developed to account for the influence and impact of the documented factors. The *Global Analysis* methodology describes two steps involved in strategy development (Hofmeister, Nord, and Soni, 2000):

##### *Step 1: Develop solutions*

A solution represents the decision to use a general process, approach, or technique to resolve a particular issue.

##### *Step 2: Develop strategies*

A strategy is the specific implementation of a solution that addresses an issue and reduces or localizes the impact of the set of related factors.

Each issue table will be expanded to include its corresponding solution and strategy as follows:

Table 6: Strategy Documentation Template

<No.>	
Name:	<Issue name>
Description:	<Description of issue>
Influencing Factor(s):	<The factor or list of factors that affect this issue>
Solution:	<Discussion of a general solution to the design issues, followed by a list of the associated strategies>
Strategy:	<Explanation of the strategy>

Each strategy will drive decisions for the underlying meta-models; thus, providing a documented and traceable framework for the governance reference model.

### 3.3.2 Modeling Design and Documentation

Reference models and architectural frameworks can be documented in a variety of ways. Service oriented architectures are typically documented using Business Process Modeling (BPM). BPM is the activity of representing both the current ("as is") and future ("to be") processes of an enterprise, so that the current process may be analyzed and improved. Modeling language standards that are used for BPM include Business Process Modeling Notation (BPMN), Unified Modeling Language (UML), and Web Services Description Language (WSDL).

BPM and UML will be used in this research to document the governance reference model and resulting architectural design. UML meta-models (figure 10) will be created based on strategies developed from issues identified in the analysis phase.

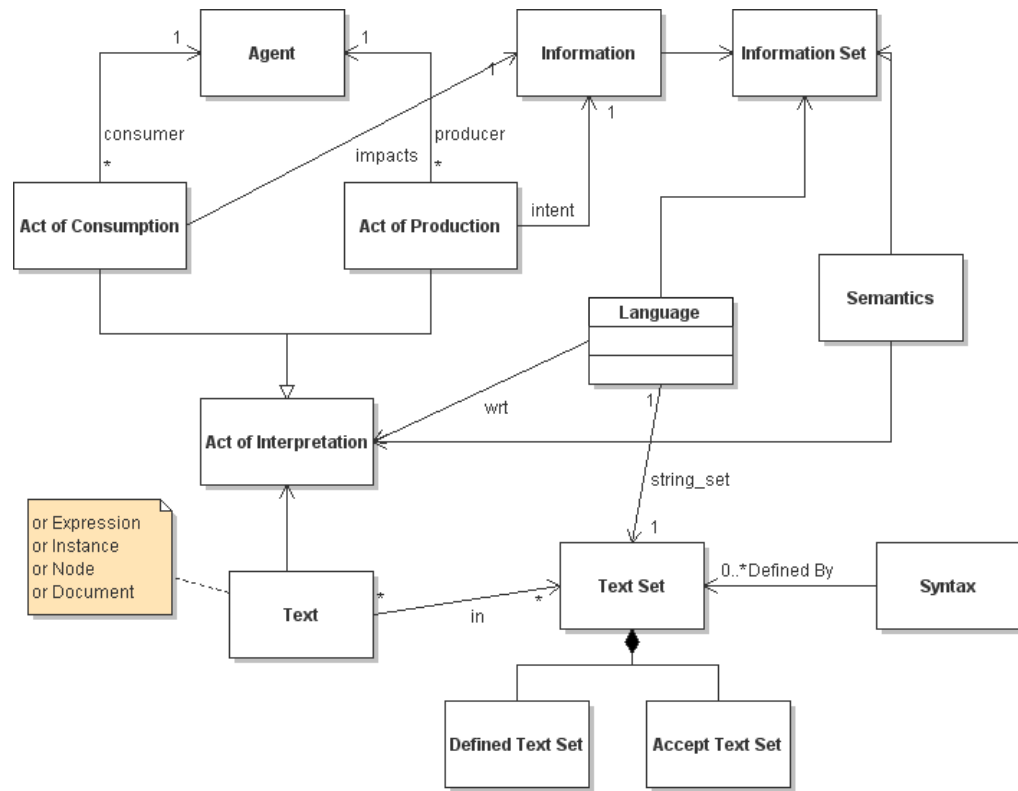


Figure 10: Unified Modeling Language Meta-model Notation

### 3.4 Phase III: Implementation Approach of SOA Governance Prototype

The implementation phase will provide the foundation for an evaluation of the governance reference model. To verify the characteristics and traits of the reference model, a prototype will be implemented that will conform to the reference model designed and documented during the previous phase. The prototype will be built to test the hypothesis, presented in Chapter 2 that an SOA-based governance reference model for common data initialization services in military simulation and C2 federation systems will:



- provide a common model to initialize common data products from various authoritative data sources
- support reusable models across varying simulations and inter-service domains
- provide common data consistency, verification, validation, and re-use models
- provide models that enable sharing of common data assets
- support common data migration & change management models

The next section provides a description and list of requirements for the prototype.

### **3.4.1 Requirements for the Prototype**

This research is focused on developing a governance reference model. A reference model is an abstract representation for understanding significant relationships among the entities of some environment. It consists of a minimal set of unifying concepts, axioms and relationships within a particular problem domain, and it is independent of specific standards, technologies, implementations, or other concrete details. The governance reference model will be validated using architectural artifacts that will drive the development of a prototype. The prototype will include a suite a tools, policies, procedures, standards, metrics, and processes required to produce common data initialization services and products for military simulation and C2 federation systems.

The following table lists the prototype requirements enumerated by type (best practice, structured interview, literature review, etc.), reference or category. The reference is associated with a publication; whereas, the category represents the categories

defined in the structured interviews section (3.2.1). Additional requirements may be identified

Table 7: Prototype Requirements Traceability Matrix

No.	Requirement	Type	Reference / Category
<i>Functional Requirements for Prototype</i>			
1	Prototype shall be a SOA-based internet application	Best Practice	OASIS, 2006
2	Prototype shall have a Graphical User Interface	Best Practice	Gartner, 2007; OASIS, 2006
3	Prototype shall include policies, processes, tools, and standards required to produce a common data initialization product	Structured Interview	Governance Category; Common Data Initialization Category
4	Prototype shall include a registry to store common data services and components	Best Practice	ZapThink, 2006; Gartner, 2007; IBM, 2006
5	Prototype shall include governance reference model and link governance activities to appropriate policies, processes, tools, metrics, and standards	Structured Interview	Governance Category
6	Prototype shall utilize web services for searching, discovering, and manipulating data	Best Practice	ZapThink, 2006; Gartner, 2007; IBM, 2006; Oracle, 2008
7	Prototype shall allow user to dynamically create, search, and download a common data service in registry	Best Practice	ZapThink, 2006; Gartner, 2007; IBM, 2006; Oracle, 2008
8	Prototype shall allow user to configure common data into common initialization formats (XML, CSV, XLS)	Structured Interview	Common Data Initialization Category
9	Prototype shall allow user to dynamically update reference model activities (policies, rules, standards, etc.)	Structured Interview	SOA Technology Category; Business Model Category
<i>Development Time Requirements for Data Services</i>			
10	Development Time to discover required standards and policies shall be collected for data service	Best Practice	Menasce, 2007; Gartner, 2007; ZapThink, 2006

No.	Requirement	Type	Reference / Category
<i>Development Time Requirements for Data Services</i>			
11	Development Time needed to identify required run-time metrics shall be collected for data service	Best Practice	Menasce, 2007; Choi, 2008; Gartner, 2007; OASIS, 2006
12	Development Time needed to assign roles and responsibilities shall be collected for data service	Best Practice	Menasce, 2007; Gartner, 2007; OASIS, 2006
<i>Development Cost Requirement for Data Services</i>			
13	Development Cost associated with the data service development shall be less than baseline data development cost	Literature Review	DoD CIO, 2006
<i>Quality of Service (QoS) Requirements for Data Services</i>			
14	Availability metrics shall be collected for data service	Best Practice	Choi, 2008; Misic, 2000; Menasce, 2007
15	Performance metrics shall be collected for data service	Best Practice	Choi, 2008; Misic, 2000; Menasce, 2007
16	Reliability metrics shall be collected for data service	Best Practice	Choi, 2008; Misic, 2000; Menasce, 2007

### 3.4.2 Governance Reference Model Goals for the Prototype

The prototype will be used as the proof-of-concept of the reference model's characteristics. Therefore, an additional set of requirements will be imposed on the prototype that will be used in the Evaluation phase to ensure that the reference model has met its goals.

Table 8: Governance Reference Model Goals and Requirements

No.	Governance Reference Model Goal	Prototype Requirement	Type	Reference / Category
1	The reference model will provide a generic platform for creating common data initialization services and products.	Prototype shall be documented to conform to the governance reference model and architectural description and specification created in Phase II.	Best Practice	OASIS, 2006; Gartner 2007
2	The reference model will support reusable data services, tools, policies, processes, and standards	Prototype shall include policies and processes for at least the following: Security, and Service Description	Structured Interview	Governance Category; SOA Category
3	The reference model will provide common data consistency, verification, validation, and re-use.	Prototype shall incorporate common data initialization services and products	Structured Interview	Governance Category; Business Model Category
4	The reference model will enable sharing of common data assets.	Prototype shall provide data services to subscribed and authorized users.	Structured Interview	SOA Category; Governance Category
5	The reference model will automate common data migration & change management.	Prototype shall incorporate a data registry for common data discovery, dissemination, and management.	Structured Interview	Governance Category; Business Model Category

### **3.5 Phase IV: Evaluation Approach of Governance Reference Model**

An evaluation of the governance reference model is important because it determines whether the modeling effort has met its goals. The evaluation verifies that the reference model has addressed the factors and issues imposed on it. The evaluation also validates the design decisions behind the reference model, ensuring the appropriate governance activities are supported.

The evaluation phase will consist of three steps:

#### *Step 1: Verification of the Prototype*

Verify the prototype against its original requirements.

#### *Step 2: Application-oriented Evaluation using Goal-Question-Metric Approach*

Ensure that each of the strategies developed in the Analysis phase had an impact on the design and implementation of the prototype.

#### *Step 3: Validation of the Reference Model*

Validate the prototype against the original research objectives to ensure those objectives have been met.

#### **3.5.1 Verification of the Prototype**

In order to verify that the prototype was built to specification, a new column will be added to its requirements table that documents whether each of its requirements has been met. Once the prototype has been completed, the prototype will be verified against each requirement as follows:

Table 9: Prototype Requirements Verification Template

No.	Requirement	Type	Reference / Category	Yes/ No
<i>Functional Requirements for Prototype</i>				
1	Prototype shall be a SOA-based internet application	Best Practice	OASIS, 2006	
2	Prototype shall have a Graphical User Interface	Best Practice	Gartner, 2007; OASIS, 2006	
3	Prototype shall include policies, processes, tools, and standards required to produce a common data initialization product	Structured Interview	Governance Category; Common Data Initialization Category	
4	Prototype shall include a registry to store common data services and components	Best Practice	ZapThink, 2006; Gartner, 2007; IBM, 2006	
5	Prototype shall include governance reference model and link governance activities to appropriate policies, processes, tools, metrics, and standards	Structured Interview	Governance Category	
6	Prototype shall utilize web services for searching, discovering, and manipulating data	Best Practice	ZapThink, 2006; Gartner, 2007; IBM, 2006; Oracle, 2008	
7	Prototype shall allow user to dynamically create, search, and download a common data service in registry	Best Practice	ZapThink, 2006; Gartner, 2007; IBM, 2006; Oracle, 2008	
8	Prototype shall allow user to configure common data into common initialization formats (XML, CSV, XLS)	Structured Interview	Common Data Initialization Category	
9	Prototype shall allow user to dynamically update reference model activities (policies, rules, standards, etc.)	Structured Interview	SOA Technology Category; Business Model Category	

No.	Requirement	Type	Reference / Category	Yes/ No
10	Development Time to discover required standards and policies shall be collected for data service	Best Practice	Menasce, 2007; Gartner, 2007; ZapThink, 2006	
11	Development Time needed to identify required run-time metrics shall be collected for data service	Best Practice	Menasce, 2007; Choi, 2008; Gartner, 2007; OASIS, 2006	
12	Development Time needed to assign roles and responsibilities shall be collected for data service	Best Practice	Menasce, 2007; Gartner, 2007; OASIS, 2006	
<i>Development Cost Requirement for Data Services</i>				
13	Development Cost associated with the data service development shall be less than baseline data development cost	Literature Review	DoD CIO, 2006	
<i>Quality of Service (QoS) Requirements for Data Services</i>				
14	Availability metrics shall be collected for data service	Best Practice	Choi, 2008; Misic, 2000; Menasce, 2007	
15	Performance metrics shall be collected for data service	Best Practice	Choi, 2008; Misic, 2000; Menasce, 2007	
16	Reliability metrics shall be collected for data service	Best Practice	Choi, 2008; Misic, 2000; Menasce, 2007	

The following use case activity diagram (figure 12) illustrates the verification process of the prototype:

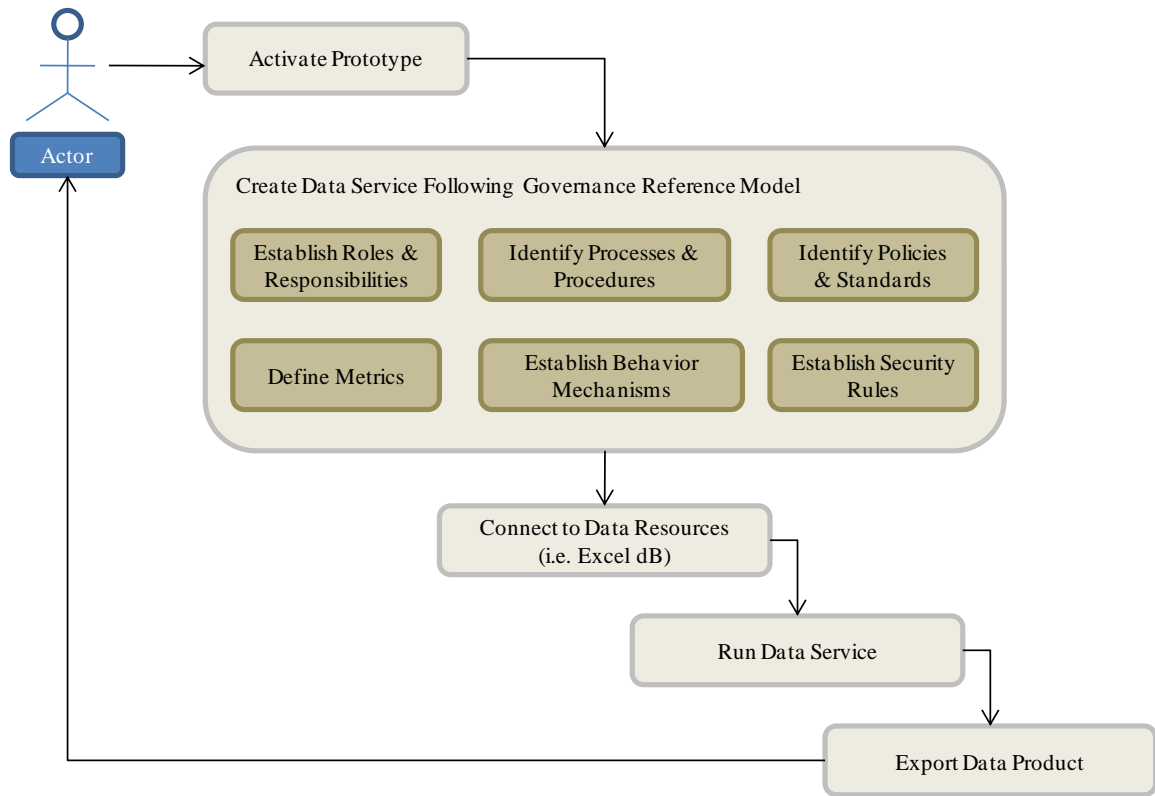


Figure 11: Use Case Activity Verification Process

### 3.5.2 Application-oriented Evaluation Using Goal-Question-Metric Approach

Because the governance reference model was built based on a set of strategies developed from stakeholder input, it is important that the implementation of the strategies be verified. Each strategy was documented in the Analysis phase, and each will be verified by documenting its impact on the prototype. The original strategies table will be expanded as follows:



Table 10: Impact Documentation Template

<No.>	
Name:	<Issue name>
Description:	<Description of issue>
Influencing Factor(s):	<The factor or list of factors that affect this issue>
Solution:	<Discussion of a general solution to the design issues, followed by a list of the associated strategies>
Strategy:	<Explanation of the strategy>
Related Strategies:	<References to related strategies and a discussion of how they are related to this issue>
Impact:	<Explanation of how the implementation of this strategy affected the implementation of the prototype>

The impact will be determined using an application-oriented evaluation based on part of the reference model supply chain methodology developed by Bohmann, Schermann, and Kremar (Bohmann, 2007). The methodology incorporates the Goal-Question-Metric (GQM) approach.

GQM is an approach to software metrics that has been promoted by Victor Basili of the University of Maryland, College Park and the Software Engineering Laboratory at the NASA Goddard Space Flight Center (Basili, 2002).

GQM defines a measurement model on three levels:

1. Conceptual level (goal)

A goal is defined for an object for a variety of reasons, with respect to various models of quality, from various points of view and relative to a particular environment.

2. Operational level (question)

A set of questions is used to define models of the object of study and then focuses on that object to characterize the assessment or achievement of a specific goal.

3. Quantitative level (metric)

A set of metrics, based on the models, is associated with every question in order to answer it in a measurable way.

The open literature typically describes GQM in terms of a six-step process where the first three steps are about using business goals to drive the identification of the right metrics and the last three steps are about gathering the measurement data and making effective use of the measurement results to drive decision making and improvements.

Basili described his six-step GQM process as follows:

1. Develop a set of corporate, division and project business goals and associated measurement goals for productivity and quality
2. Generate questions (based on models) that define those goals as completely as possible in a quantifiable way
3. Specify the measures needed to be collected to answer those questions and track process and product conformance to the goals
4. Develop mechanisms for data collection
5. Collect, validate and analyze the data in real time to provide feedback to projects for corrective action
6. Analyze the data in a post mortem fashion to assess conformance to the goals and to make recommendations for future improvements

GQM templates are a structured way of specifying goals. A GQM template contains the following fields:

Table 11: Goal-Question-Metric Template

<b>Field</b>	<b>Examples</b>
<i>object of study</i>	pair programming, static analysis tool
<i>purpose</i>	characterize, understand, evaluate, predict, improve
<i>focus</i>	programmer effort, program reliability
<i>stakeholder</i>	developer, customer, manager
<i>context factors</i>	other important factors that may affect outcomes

For the evaluation of the governance reference model, this dissertation will focus on the second stage in the reference model supply chain – solution design. In the solution design, the outputs of applying the reference model are of interest. According to Misic and Zhao, development and application of reference models is motivated by the prospect of reducing cost, enhancing revenues, or minimizing risks (Misic, 2000). In order to evaluate the output of reference modeling, the goal of this stage is improving cost, time, and Quality of Service (QoS) of the data service, which has to be supported by applying the governance reference model (DoD CIO, 2006; Choi, 2008; Misic, 2000; Menasce, 2002; Menasce, 2007). The data services created using the prototype will be evaluated based on the following GQM matrix (Bohmann, 2007; Basilli, 2002; Choi, 2008):

Table 12: Data Service Goal-Question-Metric Matrix (Menasce, 2007; Choi, 2008)

Goal	Purpose	Improve
	Issue	time, cost, and quality of
	Object / Process	data service by using governance reference model
	Viewpoint	from a designer's (service developer) point of view
<b>Question 1</b>	<b><i>Did the application of the governance reference model affect the development time of the data service?</i></b>	
	<b>Metric 1</b>	Time needed to discover required standards and policies (TS)
	<b>Metric 2</b>	Time needed to identify required run-time metrics (TM)
	<b>Metric 3</b>	Time needed to assign roles and responsibilities (TR)
<b>Question 2</b>	<b><i>Did the application of the governance reference model affect the development cost of the data service?</i></b>	
	<b>Metric 4</b>	Approximate cost associated with the data service development ((TS + TM + TR) x average hourly rate))
<b>Question 3</b>	<b><i>Did the application of the governance reference model affect the QoS of the data service?</i></b>	
	<b>Metric 5</b>	Availability: ○ Data Service Request Count
	<b>Metric 6</b>	Performance: ○ Data Service Average Response Time
	<b>Metric 7</b>	Reliability: ○ Data Service Response Count / Data Service Failure Count

The metrics data for *Time* (TS, TM, and TR) will be collected by the prototype using a time-watch function that will start when a new service is created, and will stop when the new service is submitted into the registry. The metrics data for *Cost* is determined by calculating the product of the total *Time* metrics and average hourly rate (based on industry standard). The metrics data for *Availability*, *Performance*, and *Reliability* will be collected by the prototype application based on standard computing functions (Bohmann, 2007; Basilli, 2002; Choi, 2008).

### **3.5.3 Validation of the Governance Reference Model**

In order to ensure that the governance reference model has met the original research objectives, it is necessary to show how the prototype has met those objectives. This will be done by ensuring that the prototype has met the reference model requirements specified in Phase III in the following table:

Table 13: Governance Reference Model Goals and Requirements Validation Template

No.	Governance Reference Model Goal	Prototype Requirement	Type	Reference / Category	Yes/ No
1	The reference model will provide a generic platform for creating common data initialization services and products.	Prototype shall be documented to conform to the governance reference model and architectural description and specification created in Phase II.	Best Practice	OASIS, 2006; Gartner 2007	
2	The reference model will support reusable data services, tools, policies, processes, and standards	Prototype shall include policies and processes for at least the following: Security, and Service Description	Structured Interview	Governance Category; SOA Category	
3	The reference model will provide common data consistency, verification, validation, and re-use.	Prototype shall incorporate common data initialization services and products	Structured Interview	Governance Category; Business Model Category	
4	The reference model will enable sharing of common data assets.	Prototype shall provide data services to subscribed and authorized users.	Structured Interview	SOA Category; Governance Category	
5	The reference model will automate common data migration & change management.	Prototype shall incorporate a data registry for common data discovery, dissemination, and management.	Structured Interview	Governance Category; Business Model Category	

### **3.6 Contribution of the Research**

This research represents the implementation of a new strategy for the development of common data initialization services in military simulation and C2 federation systems using service-oriented architecture techniques. It is based on the analysis of the governance activities of military simulation and C2 federation stakeholders. This strategy provides a solution for the drawbacks encountered through other common data initialization strategies like point-to-point, client-server, and centralization.

A new governance reference model will be developed that, when followed, will provide a common model from which common initialization data services for military simulation and C2 federation systems can be created. The governance reference model will be created systematically and documented through notation presented in the literature. It will be capable of supporting many types of SOA-based common data services, and incorporating its respective governance elements (policies, standards, rules, metrics, behaviors, etc.). Furthermore, the governance reference model will provide opportunity and direction for future research in other SOA development activities.

In general, the governance reference model will be high-level and technically independent of the use case presented in this dissertation. Thus, allowing the governance reference model to be applied to any data service component developed in a service-oriented architecture implementation by open-source communities, government, or industry.

## **4.0 RESEARCH DATA COLLECTION, ANALYSIS, AND FINDINGS**

This chapter presents and documents the data collection, analysis, and findings from executing the research outlined in the previous chapter. That research had as an overall goal review of the Lanman & Proctor Conceptual Governance Reference Model (Lanman, 2009) and other SOA literature by experts in the field in order to advance a more complete and general reference model for SOA governance. The scope of research investigated five general hypotheses related to the governance reference model. Those hypotheses were that a conceptual governance reference model will:

- provide a common model to initialize common data products from various authoritative data sources
- support reusable models across varying simulations and inter-service domains
- provide common data consistency, verification, validation, and re-use models
- provide models that enable sharing of common data assets
- support common data migration & change management models

Also, this chapter presents and documents the following products:

- Structured Interview Data: (Appendix A)
  - Nine interviews were conducted with Subject Matter Experts (SMEs) in the fields of service oriented architecture, governance, business models, and data initialization. The SME input was collected using structured questionnaires and analyzed to identify factors and impacts.



- Factors and Impacts:
  - An analysis of the structured interviews produced a list of factors and impacts (Appendix B) that the SMEs perceived to be critical to the design consideration of the revised governance reference model. Factors are grouped into a set of related fundamental issues.
- Issues – Solutions and Strategies:
  - For each fundamental issue identified, a general modeling solution was identified that would be used to resolve the issue or mitigate its impact. For each solution, one or more specific design strategies were developed that would help define the structure of the revised governance reference model (Appendix C).
- Revised Governance Reference Model:
  - The revised governance reference model is derived from interviews with SMEs and corresponding factors, issues, solutions and strategies, and documented using UML (Appendix D).
- Governance Reference Model Developmental Process: Stages and Threads:
  - The governance model developmental process is derived from SME insights and strategies, and organizational best practices. The process is used to drive the creation of a high-level architectural design that incorporates revisions to existing SOA design and moves it all into what is referred to below as Governance-oriented SOA (G-SOA).

- Governance-oriented Service Oriented Architecture (G-SOA):
  - As a revision to the traditional Service-oriented Architecture, a Governance-oriented SOA is proposed. The G-SOA design is implemented using the easily understood Business Process Modeling (BPM) notation (section 4.3.2). Further a prototype is implemented that conforms to G-SOA (Appendix E).
- Prototype:
  - The prototype is a Governance-oriented SOA-based application implemented using web-services technology (section 4.3.3). The implementation is driven by the G-SOA described above.
- Data and Analysis:
  - The revised governance reference model, proposed G-SOA, and prototype are evaluated based on requirements identified by expert input and published organizational best practices (section 4.4).

The data collection, analysis, synthesis, and evaluations described below were conducted in four phases.

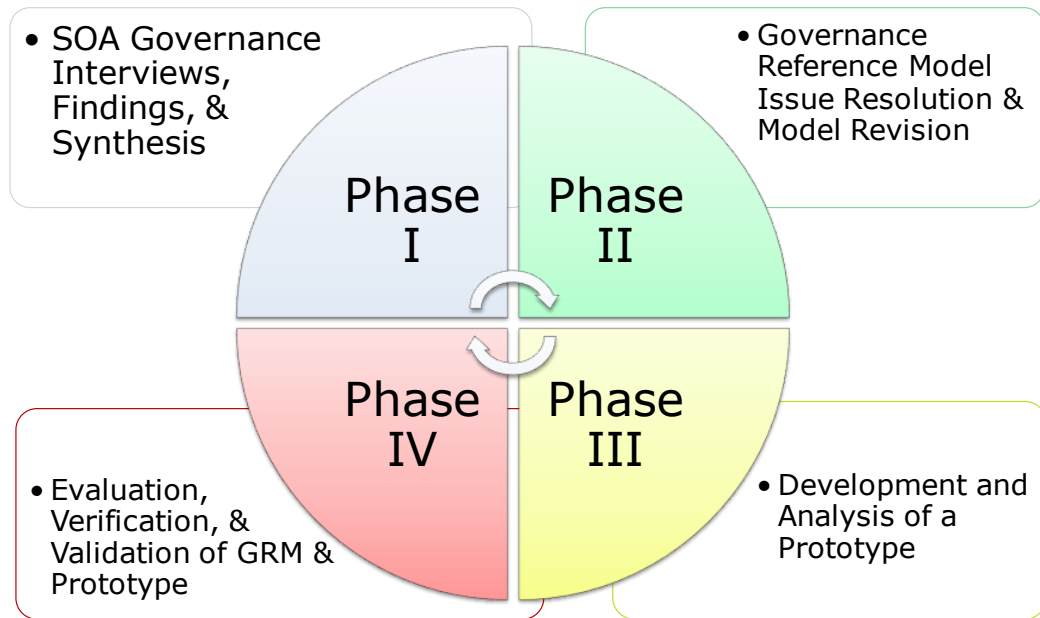


Figure 12: Research Concept and Methodology Phases

1. Phase I: “SOA Governance Interviews, Findings, and Synthesis” includes the write-ups from interviews with nine experts and it documents the factors and issues they identified that the governance reference model must address.
2. Phase II: “Governance Reference Model Issue Resolution and Model Revision” documents the design decisions and governance reference model description diagrams.
3. Phase III: “Development and Analysis of Prototype” describes the governance reference model implementation and prototype development.
4. Phase IV: “Evaluation, Verification, and Validation of Governance Reference Model and Prototype” presents the evaluation of the prototype as verification and validation that the governance reference model exhibits the characteristics required to meet its original objectives.

#### **4.1 Phase I: SOA Governance Expert Interviews, Findings and Synthesis**

In the “SOA Governance Interviews, Findings, and Synthesis” phase, nine interviews were conducted with experts in the fields of service oriented architecture, governance, business models, and data initialization. Analysis of the interview findings produced a list of factors that would affect the type of governance reference model created in this dissertation. The factors were grouped together to produce a set of fundamental issues that the governance reference model would need to address.

##### **4.1.1 Structured Interviews and Expert Assessments**

Nine subject matter experts in areas of SOA, governance, and business models in data initialization of SOA-based military simulation and C2 systems were interviewed. The following summarizes the interviewees’ domain expertise, title, and respective organization:

- Service Oriented Architecture (4)
  - Senior Research Scientist – Software Engineering Institute, Carnegie Mellon University, Pittsburgh, PA
  - Professor – Virginia Modeling and Simulation Center, Old Dominion University, Norfolk, VA
  - Principal Modeling & Simulation Engineer – MITRE Corporation, Mclean, VA
  - Chief SOA Architect – Gartner, Inc., Stamford, CT
- Governance (3)

- Senior Policy Advisor, U.S. Army Program Executive Office Simulation, Training, and Instrumentation, Orlando, FL
- Professor and Senior Technical Staff – Naval Postgraduate School, Monterrey, CA
- Director of Architectural Policy – Modeling and Simulation Coordination Office, Office of the Secretary of Defense, Washington, D.C.
- Business modeling (2)
  - Chief of Staff – U.S. Army Research, Development, and Engineering Command, Washington, D.C.
  - Senior Principal Systems Engineer – MITRE Corporation, Mclean, VA

The completed expert interview questionnaires are documented in Appendix A.

#### **4.1.2 Synthesis of Expert Assessments into Governance Design Factors**

An analysis of the interviews produced the following list of factors that the subject matter experts believed were critical to the design consideration for the governance reference model.

1. Incorrect data services and solutions are built that do not meet the needs of the enterprise
2. Inconsistent approach to discovery, consumption, identification, design, development, implementation, and management of data services and solutions
3. SOA governance approach is not being properly communicated throughout the organization
4. Data services have undocumented ownership

5. Only unapproved data services are deployed
6. Data services created do not adhere to governance policies
7. Data services are designed, built, and run in an unsecure manner
8. Changes to data services are not managed
9. Data services are not managed in a scalable way
10. Data service developers cannot easily publish and discover services
11. SOA governance controls and exception policies do not exist and are ineffective
12. Appropriate and pragmatic SOA governance roles, responsibilities, and authority are not understood and being executed in an unacceptable manner
13. Little vitality in the governance process; SOA governance is not maturing as the SOA capabilities of the organization mature
14. Understanding current governance structures
15. Assessing SOA governance maturity
16. Developing SOA governance vision and strategy, scope, principles, and roadmap
17. Data service identification and appropriate reuse
18. Demonstrating the quality of SOA governance solutions
19. Data service solution portfolio management
20. Ensuring data services satisfy business requirements
21. Lack of data service interoperability
22. Uncontrolled proliferation of data services
23. Cross-organization coordination
24. Data service metrics and quantifiable measures

The full description of each factor including categorization, characterization, and analysis of impact can be found in Appendix B.

#### **4.1.3 Synthesis of Expert Assessments into Governance Design Issues**

Similar factors were grouped together to help identify the fundamental issues that the architecture must address. Following is the list of issues that were identified:

1. Adoption of data service governance reference model
2. Realization of data service governance
3. Execution of data service governance
4. Enforcement of data service governance compliance
5. Data service protection via security rules
6. Data service enforcement via policies and standards
7. Data service implementation via processes and procedures
8. Data service management via roles and responsibilities
9. Data service monitoring via metrics
10. Data service motivation via behaviors

A full description of each issue and its associated influencing factors can be found in Appendix C.

#### **4.2 Phase II: Governance Reference Model Issue Resolution and Model Revision**

The design and documentation of the governance reference model presents the results of the effort to create a resolution to the issues identified in Phase I. Solutions and

design strategies are identified and the reference model's objects and relationships are defined.

Figure 13 below illustrates the *initial* Conceptual Governance Reference Model described by Lanman and Proctor prior to the SME interviews (Lanman, 2009). The model conceptually illustrates the components that make up a proposed governance reference model for data services in simulation federations.

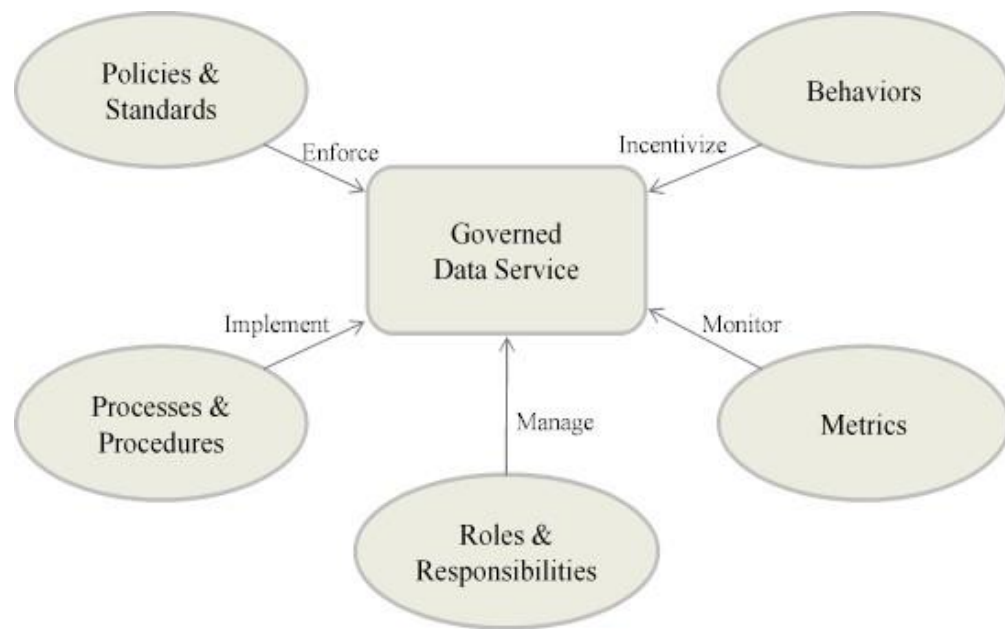


Figure 13: Conceptual Governance Reference Model for Data Services

The essence of the SME interviews was to extend and create greater fidelity to the initial conceptual governance reference model. Section 4.2.2 presents the *revised* Conceptual Governance Reference Model and describes the changes motivated by SME interviews and organizational best practices.



#### 4.2.1 Model Issue Identification and Resolution: Solutions and Strategies

For each issue identified in the analysis phase, a general modeling solution was identified that would be used to resolve the issue or mitigate its impact. For each solution, one or more specific design strategies were developed that would help define the structure of the governance reference model.

The proposed solutions to each of the numbered issues along with associated design strategies are as follows:

1. Adoption of a governance model

**Solution:** Use of the approved governance artifacts, from the SOA governance model, will reduce data service risk and lower costs, by reducing the number and complexity of design activities in the data service. Organization governance models may be based on standard SOA governance models or industry governance models. All SOA governance solutions should be created based on the organization's SOA governance model.

**Strategy:** Reference and adopt industry best practices and integrate with organizational best practices and specific needs.

2. Realization of data service governance

**Solution:** Ensure that an organization is willing to develop and support a needed data service long-term, especially if data services may be used across organization activities. Data services developed on an ad hoc basis may not be officially supported for defects, conformance, enhancement, and performance.

**Strategy:** Develop a governance framework.

**Strategy:** Identify data service requirements.

**Strategy:** Charter data service governance body.

**Strategy:** Identify data service stakeholders.

**Strategy:** Identify policies and processes.

3. Execution of data service governance

**Solution:** Ensure proper execution of governance by communicating SOA governance value, and appropriate SOA governance policies and processes.

**Strategy:** Define management delegation.

**Strategy:** Mandate and interpret rules.

**Strategy:** Identify and implement standards and regulations.

**Strategy:** Generate and execute policies.

4. Enforcement of data service governance compliance

**Solution:** Ensure high-quality data services and conditions are met that have been expressed to achieve stated goals.

**Strategy:** Initiate actions that result in enforcement.

**Strategy:** Apply incentives or penalties against data service stakeholders.

**Strategy:** Define metrics available to stakeholders, governance body, and management.

**Strategy:** Management guided by policies and processes.

5. Data service protection via security rules

**Solution:** Ensure correct security levels and risk levels.

**Strategy:** Empower data service stakeholders with authority.

**Strategy:** Authenticate data service stakeholder identity and authority.

**Strategy:** Define policy rules and process steps for authorization.

6. Data service enforcement via policies and standards

**Solution:** Ensure data service providers are adhering to current operational and tactical policies and standards established by authority, custom, or general consent as a model.

**Strategy:** Enforce data service contract defined by policy.

**Strategy:** Govern policy constraints.

**Strategy:** Translate policy from guidelines.

**Strategy:** Identify metrics to provide measures for policies and standards.

7. Data service implementation via processes and procedures

**Solution:** Implement data service steps for design, development, testing, implementation, deployment, and sustainment that conform to policies and standards.

**Strategy:** Define guidelines based on rules, regulations, and standards.

**Strategy:** Define governing processes by compliance, communication, and dispensation.

**Strategy:** Define governed processes by data service lifecycle and data service portfolio management.

8. Data service management via roles and responsibilities

**Solution:** Manage data service roles and responsibilities considered as part of an organization's SOA governance model. Which roles apply will be a

function of the governance principles and SOA governance maturity. The role name is not as important as the responsibilities highlighted. Each organization has their own role naming conventions and it is more important to adopt/align the new governance responsibilities with the existing internal structures.

**Strategy:** Establish roles for data service stakeholders, sponsors, governance body, management, and service lifecycle.

**Strategy:** Create additional custom roles and responsibilities for the organization unique to the business activities.

**Strategy:** Identify responsibilities for security, policies, processes, metrics, and behaviors.

#### 9. Data service monitoring via metrics

**Solution:** Monitor data services using metrics that provide the technical basis for evaluating the effectiveness of the SOA and determining the order in which data services should be built as it moves towards the architecture vision. Metrics give ways to prioritize data services and determine the largest return on investment (ROI) within an organization.

**Strategy:** Define metrics for policies, processes, and behaviors.

**Strategy:** Guide decisions tracked by compliance measurement

**Strategy:** Provide metrics for management, data service stakeholders, and data service governance body.

#### 10. Data service motivation via behaviors

**Solution:** Emplace incentive and penalty mechanisms for appropriate behaviors for design, development, conformance, sustainment, and use of data services.

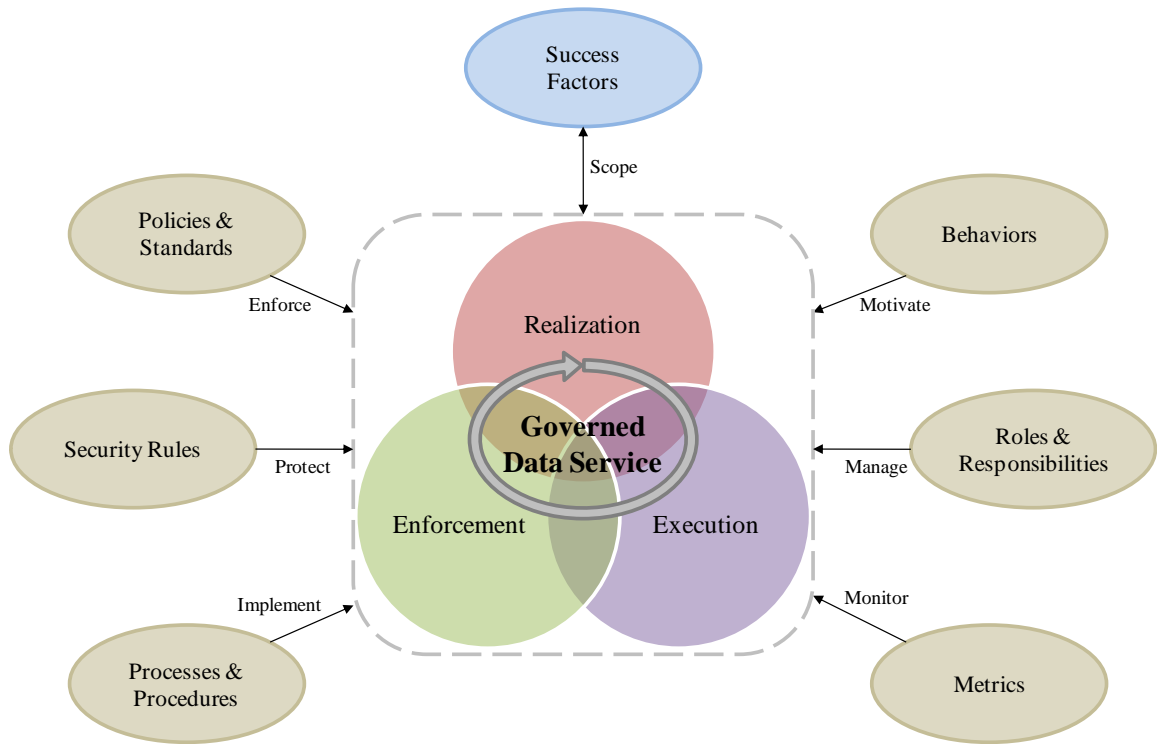
**Strategy:** Determine incentive and penalties based on behavioral service usage.

**Strategy:** Maintain metrics available to data service stakeholders.

A full description of each solution, each solution's design strategies, and related strategies can be found in Appendix C.

#### **4.2.2 Conceptual Governance Reference Model Revisions: Stages and Threads**

This section provides a brief description of a revision of the Lanman and Proctor *initial* Conceptual Governance Reference Model that is based on solutions to issues identified by the SMEs and strategies proposed above to address those issues. Within this section the development of the *revised* Conceptual Governance Reference Model is described in stages and threads.



**Figure 14: High Level Conceptual Governance Reference Model**

Figure 14 illustrates the *revised* Conceptual Governance Reference Model based on changes motivated by SME interview data synthesis and published organizational best practices. The following summarizes the major differences between the revised model (figure 14) and the initial model (figure 13) presented earlier.

- Addition of Realization Stage: The Realization stage provides overall governance structure and service governance definition.
- Addition of Execution Stage: The Execution stage provides operational structure.
- Addition of Enforcement Stage: The Enforcement stage provides conformance structure

- Addition of Security Rules Thread: The Security Rules thread provides governance guidance on data service protection.
- Addition of Success Factors Thread: The Success Factors thread provides bidirectional scoping of data service and organizational success criterion.

The three abstract stages were developed to address issues identified by SMEs and organizational best practices in the realization, execution, and enforcement of the underlying core governance, operation, and conformance structures. Further it was identified by SMEs and literature that security, and a driving success model that identifies criterion for commitment and resources was a major concern in the overall governance theme. As a result, a security use case thread and a success factors use case thread was developed to address data service protection and scope respectively.

#### **4.2.3 Governance Reference Model Developmental Process: Stages and Threads**

This section describes how the governance reference model developmental process methodology was developed to create a governance reference model and governance-oriented Service-oriented architecture. The process is generic so that it can be used for more general applications.

##### **1. Governance Reference Model Developmental Process: Stages**

Generic development of SOA governance can be associated with three abstract stages: realization, execution, and enforcement. Their assigned responsibilities are listed below.

- *Realization*: This stage provides the underlying core governance structure for applying governance in an environment. It is responsible for defining

governance and a governance body, establishing policies and processes, and the overall governance structure for stakeholders.

- *Execution*: This stage provides the operational structure for managing the service lifecycle.
- *Enforcement*: This stage provides the conformance structure for ensuring the adherence of a service to the governance model.

## **2. Governance Reference Model Developmental Process: Threads**

Seven generic use case threads that drive successful governance was also identified: success factors, security rules, policies and standards, processes and procedures, roles and responsibilities, metrics, and behaviors. Their assigned responsibilities are listed below.

- *Success Factors*: This thread provides a bidirectional scoping structure for a service and organization.
- *Security Rules*: This thread provides a protection structure for a service.
- *Policies and Standards*: This thread provides an enforcement structure for a service.
- *Processes and Procedures*: This thread provides an implementation structure for a service.
- *Roles and Responsibilities*: This thread provides a management structure for a service.
- *Metrics*: This thread provides a monitoring structure for a service.
- *Behaviors*: This thread provides a motivation structure for a service.



The process above is used to develop the revised Governance Reference Model that drives the G-SOA. The product of the process, revised Governance Reference Model and G-SOA, can provide feedback for process improvement back into the original process. During the development of the G-SOA using the process, a new high-level issue (establishing a governance body) was identified in the Realization stage that was appropriate for integration back into the original process.

#### **4.2.4 Revised Governance Reference Model: Stages and Threads**

The following sections describe the three abstract stages and use case threads of the revised governance reference model using the Governance Reference Model Developmental Process. The revised governance reference model is in turn used to drive development of the governance-oriented service-oriented architecture (G-SOA).

- **Stage 1: Realization of Data Service Governance**

Data service governance requires an appropriate organizational structure and identification of who has authority to make governance decisions. In this model, the entity with governance authority is designated the Data Service Governance Body. This is a group that Data Service Stakeholders recognize as having authority and who typically has some control over the Data Service Stakeholders (OASIS, 2006).

The Data Service Governance Body is responsible for delegating a working group to prescribe the Governance Framework that forms the structure for Governance Processes that define how governance is to be carried out. This does not itself define the details of how governance is to be applied, but it does

provide an unambiguous set of procedures that should ensure consistent actions which Data Service Stakeholders agree are fair and account for sufficient input on the subjects to which governance will be applied. Note that the Policies and Processes should also include those necessary to modify the Governance Framework itself. The Policies and Processes are reviewed and agreed to by the Data Service Stakeholders. The Governance Framework, and Policies and Processes are often documented in the charter of a body created or designated to oversee governance (OASIS, 2006).

An important function of Data Service Governance Body is not only to initiate but also be the consistent supporter of governance. Those responsible for carrying out governance mandates must have a Data Service Governance Body who makes it clear to Data Service Stakeholders that expressed Policies are seen as a means to realizing established goals and that compliance with governance is required (OASIS, 2006; OpenGroup, 2009).

- **Stage 2: Execution of Data Service Governance**

To carry out governance, the Data Service Governance Body promulgates the Rules, Regulations, and Standards needed to make the Policies and Processes operational. The Data Service Governance Body acts in line with Processes for its rule-making process and other functions. Whereas Governance is the setting of Policies and defining the Rules that provide an operational context for Policies, the operational details of governance are likely delegated by the Data Service Governance Body to Management (OASIS, 2006).

Management generates Regulations that specify details for Rules and other procedures to implement both Rules and Regulations. For example, the Data Service Governance Body could set a policy that all authorized parties should have access to data, the Data Service Governance Body would promulgate a Rule that PKI certificates are required to establish identity of authorized parties, and Management can specify who it deems to be a recognized PKI issuing body (OASIS, 2006).

Whereas the Governance Framework and Processes are fundamental for having Data Service Stakeholders acknowledge and commit to compliance with governance, the Rules and Regulations provide operational constraints which may require resource commitments or other levies on the Data Service Stakeholders. It is important for Data Service Stakeholders to consider the framework and processes to be fair, unambiguous, and capable of being carried out in a consistent manner and to have an opportunity to formally accept or ratify this situation. Rules and Regulations, however, do not require individual acceptance by any given participant although some level of community comment is likely to be part of the Processes. Having agreed to governance, the Data Service Stakeholders are bound to comply or be subject to prescribed mechanisms for enforcement (OASIS, 2006).

- **Stage 3: Enforcement of Data Service Governance Compliance**

Setting Rules and Regulations does not ensure effective governance unless compliance can be measured and Rules and Regulations can be enforced. Metrics

are those conditions and quantities that can be measured to characterize actions and results. Rules and Regulations must be based on collected Metrics or there will be no way for Management to assess compliance. The Metrics are available to the Data Service Stakeholders, and the Data Service Governance Body so what is measured and the results of measurement are clear to everyone (OASIS, 2006).

The Data Service Governance Body in its relationship with Data Service Stakeholders will have certain options that can be used for Enforcement. A common option may be to affect future funding. The Data Service Governance Body defines specific enforcement responses, such as what degree of compliance is necessary for full funding to be restored. It is up to Management to identify compliance shortfalls and to initiate the Enforcement process (OASIS, 2006).

Note that enforcement does not strictly need to be negative. Management can use Metrics to identify exemplars of compliance and the Data Service Governance Body can provide options for rewarding the Data Service Stakeholders. It is likely the Data Service Governance Body that defines awards or other incentives (OASIS, 2006).

The following sections further describe the six use case threads based on SME input and organizational best practices.

- **Thread 1: Data Service Success Factors Governance**

Success Factors governance can be characterized in terms of key success criterion that define the overall scope for data services and the organization. Success

criterion to be established include: Mission and Vision, Planning, Resources, Technology, and Content.

- *Mission and Vision:* This success factor concerns the overall organizational mission and vision in the planning, implementation, and execution of data services.
- *Planning:* This success factor provides structure for implementing data services strategies.
- *Resources:* This success factor provides structure for people, processes, and budget that develop data services.
- *Technology:* This success factor provides structure for software, access, infrastructure, and tools that enable data services.
- *Content:* This success factor provides structure for layout, design, and usability of data services.

While the aforementioned success factors are important in defining scope for data services and organizations, it is also important to enlist and ensure executive support and user motivation. Executive support can be characterized by the data service governance body; whereas, user motivation can be characterized by behaviors and patterns.

- **Thread 2: Data Service Security Rules Governance**

Security Rules governance can be characterized in terms of key security concepts: Confidentiality, Integrity, Authentication, Trust, and Authorization.

- *Confidentiality*: This security concept concerns the protection of privacy of Data Service Stakeholders in their interactions. Confidentiality refers to the assurance that unauthorized entities are not able to read messages or parts of messages that are transmitted (OASIS, 2006).
- *Integrity*: This security concept concerns the protection of information that is exchanged – either from unauthorized writing or inadvertent corruption. Integrity refers to the assurance that information that has been exchanged has not been altered. Integrity is different from Confidentiality in that messages that are sent from one Data Service Stakeholder to another may be obscured to a third party, but the third party may still be able to introduce his own content into the exchange without the knowledge of the Data Service Stakeholders (OASIS, 2006).
- *Authentication*: This security concept concerns the identity of the Data Service Stakeholders in an exchange. Authentication refers to the means by which one participant can be assured of the Identity of other Data Service Stakeholders (OASIS, 2006).
- *Authorization*: This security concept concerns the legitimacy of the interaction. Authorization refers to the means by which an owner of a resource may be assured that the information and actions that are exchanged are either explicitly or implicitly approved. Authorization assesses the Attributes, Behaviors, and Roles associated with Data Service Stakeholder activity (OASIS, 2006).

- *Trust*: This security concept concerns the accountability of participants.

To foster trust in the performance of a system used to conduct shared activities it is important that the Data Service Stakeholders are not able to later deny their actions: to repudiate them. Non-repudiation refers to the means by which a participant may not, at a later time, successfully deny having participated in the interaction or having performed the actions as reported by other Data Service Stakeholders (OASIS, 2006).

Note that these security goals are never absolute: it is not possible to guarantee 100% Confidentiality, Trust, etc. However, a well designed and implemented security response model can ensure acceptable levels of security risk (OASIS, 2006).

While Confidentiality and Integrity can be viewed as primarily the concerns of the direct Data Service Stakeholders in an interaction; Authentication, Authorization, and Trust imply the Data Service Stakeholders are acting within a broader social structure (OASIS, 2006).

- **Thread 3: Data Service Policies and Standards Governance**

Policies and standards prescribe the conditions and constraints for interacting with a service and impact the willingness to continue visibility with the other participants. Whereas technical assumptions are statements of “physical” fact, policies are subjective assertions made by the service provider (sometimes as passed on from higher authorities) (OASIS, 2006).

Policies and standards are the cornerstone of governance. They are the set of goals by which one directs and measures success. Policies need to be developed based on the impact to operations and the reliability required of the data services created. As data services are added and the SOA evolves, new policies need to be created and old policies need to be changed or retired. Current policies should be collected and made available to service developers. Policies and standards from both the technology and operational and tactical areas defining governance best practices across the federation are required. Relevant areas include: performance, security, government doctrine and mandates, registration process details (OASIS, 2006).

Policies, standards, and data service contracts can contain a mix of permissions and obligations, and, in sufficiently rich policy management frameworks, can be combined in interesting ways: for example, you may be obliged to give permission to certain actions; or you may be permitted to enter into obligations (this is the core of the right to enter into contracts). The mechanism for enforcing a permission-oriented constraint is typically prevention at the point of action. The mechanisms for enforcing obligation constraints are typically achieved by a combination of auditing and remedial action (OASIS, 2006).

- **Thread 4: Data Service Processes and Procedures Governance**

Governing processes and procedures realize the governance intentions of the organization. These are the processes and procedures that a governance model



uses to govern any particular process. Governed processes are the actual processes being controlled, monitored, and measured (e.g., testing, design, and deployment) (OASIS, 2006).

This model defines three governing processes: Compliance, Dispensation, and Communication, which are performed on an ongoing basis.

- *Compliance*: The purpose of this activity is to define a method to ensure that the SOA policies, guidelines, and standards are adhered to. The Compliance process provides the mechanism for review and approval or rejection against the criteria established in the governance framework (i.e., principles, standards, roles, and responsibilities, etc.). In many cases, it is an add-on to the existing quality review process. A suggested method is to insert SOA Governance Checkpoints into the defined SOA processes defined below (Service & Solution Portfolio and Lifecycle). These checkpoints can be manual reviews by responsible parties or automated, programmatic checkpoints (OpenGroup, 2009).
- *Dispensation*: The Dispensation process is the exception and appeals process that allows a project or application team to appeal non-compliance to established processes, standards, policies, and guidelines as defined within the governance regimen. Examples include service funding, service ownership, service identification, etc. The result would be a granted exception (OpenGroup, 2009).

- *Communication*: Communication processes educate, communicate, and support the SOA Governance Model and SOA policies, guidelines, and standards across the organization. This also includes ensuring that the governing processes are acknowledged within the governed processes. Communication processes should ensure that the governance is understood. It should also ensure access to and use of governance information (OpenGroup, 2009).

Governed processes and procedures include instantiations that result in a set of SOA processes to provide ongoing management of the SOA solution. The Portfolio Management process focuses on planning and prioritization of individual SOA solutions. These individual solutions may consume existing services as well as define new services. Following the guidance of the Service Portfolio Management process, these solutions may consume the reusable services developed by the Service Lifecycle process and/or define new services for Service Portfolio Management. The new services are thereby prioritized by Service Portfolio Management for the Service Lifecycle process to manage for consumption by the individual SOA solutions. The Lifecycle then enforces the Portfolio Management plans during the development, deployment, and management of the individual SOA solution (OASIS, 2006; OpenGroup, 2009).

- **Thread 5: Data Service Roles and Responsibilities Governance**

Below is the recommended minimum set of roles and responsibilities that should be considered as part of an organization's SOA Governance Model. Which

roles apply will be a function of the governance principles and SOA governance maturity. The role name is not as important as the responsibilities highlighted. Each organization has their own role naming conventions and it is more important to adopt/align the new governance responsibilities with the existing internal structures (OpenGroup, 2009).

- *Data Service Sponsor*: Represents the business organizations.
- *Data Service Stakeholders*: Collaborate to develop SOA, Governance Roadmap, Transition Plans, and governance principles. Define and develop SOA governing processes and best practices. Define where compliance checkpoints should be inserted into governed SOA processes. Define and monitor SOA metrics. Provide architectural definition and integration support across SOA solution. Initiate SOA and SOA governance organizational changes. Develop governed SOA transformation plans. Identify SOA training and mentoring plans. Define and validate changes to the project management process. Select and implement the SOA governance tool strategy (OpenGroup, 2009).
- *Data Service Governance Body*: Define and develop the data service portfolio (segment/domain architecture). Ensure compliance with standards, guidelines, dispensation, and communication (OpenGroup, 2009).
- *Management*: Responsible for the solution from a business perspective by justifying the solution and service existence, and continuous operation to

the data service stakeholders. Determine business service functionality. Communicate business requirements and identify business services for each domain. Share information regarding specific business requirements and identify the cross-organizational SOA business services. Work on prioritizing program requirements and services. Develop service proposals to go through funding process (OpenGroup, 2009).

- *Service Lifecycle*: Design, development, testing, deployment, execution, and delivery of the services. Maintain interfaces to its services. Follow standards and guidelines. Understand and abide by the governing processes (OpenGroup, 2009).

These roles and structures are provided as a starting point for customization of a SOA Governance Model. A subset of these roles and/or structures could be selected. Different organizations might decide, for simplicity, to have combined organizational structures to support the roles. Additional roles unique to the organization may be defined (OASIS, 2006; OpenGroup, 2009).

- **Thread 6: Data Service Metrics Governance**

A major requirement for ensuring well-behaved data services will be collecting sufficient metrics to know how the data service affects the SOA infrastructure and whether it complies with established infrastructure policies. Four significant entities that drive metrics include: Audit, Conformance, Enforcement, and Decision:

- *Audit*: The Audit is any mechanism that records Data Service Stakeholder actions requiring permission decisions or records the measurement results for obligations. An auditing mechanism may store audited information and/or provide event notifications of audited information. Auditing may be used for activities like forensic investigation and regulatory compliance (OpenGroup, 2009).
- *Conformance*: Conformance ensures that data services conform to the rules and regulations set by policies and standards, and steps set by processes (OpenGroup, 2009).
- *Enforcement*: Enforcement enforces and assures the Decision and obligations. In a Service Oriented Architecture, one policy or contract may be applicable to multiple distributed services. Due to the distributed nature of a SOA, the enforcement of permission decisions is attributed to an Enforcement point that is separate from the Decision point. One Decision point can provide decisions for many distributed Enforcement points (OpenGroup, 2009).
- *Decision*: The Decision evaluates Data Service Stakeholders requests against relevant policies/contracts and attributes to render a permission decision. The Decision provides a measurement for an assertion. The Decision generally renders a permission decision in the form of permit, deny, indeterminate, not applicable, or a set of obligations. A Decision may obtain a permission decision from a computing mechanism or from

outside the computing system, decisions by people through workflow for example (OpenGroup, 2009).

- **Thread 7: Data Service Behaviors Governance**

To ensure Quality of Service for data services, it is recommended to include a model for collecting Data Service Stakeholder behaviors and patterns. Behaviors and Patterns determine Incentive or Penalty depending on the data service application and usage. Behavior is important to a governance reference model. Supporting a set of distributed data services requires an increased level of social interaction between the different Data Service Stakeholders (OpenGroup, 2009).

Typically Data Service Stakeholders are rewarded on how well they meet cost, schedule, and performance as opposed to how well the program completes a certain capability or how much closer the system is towards attaining the architectural vision. This dissertation does not intend to convey that cost, schedule, and performance should be ignored, but instead suggests that additional evaluation criteria need to be added to help facilitate discussion and interaction. Data Service Stakeholders are dependent upon funds to continue; therefore, setting certain incentives, penalties, and rewards for successful “SOA behavior” would be a possible first step toward achieving optimal interoperability and reuse. Withholding a certain percentage of funding from each Data Service Stakeholder until a minimum level of SOA behavior is met would be an example (OpenGroup, 2009).

The *revised* conceptual governance reference model diagrams can be found in Appendix D.

### **4.3 Phase III: Development and Analysis of Prototype**

This section provides details on the development and run-time environment of the prototype. The prototype provides concrete specifications relating to how the revised governance reference model and developmental process of stages and threads may be implemented to create an application specific Governance-oriented SOA. Discussion below indicates how that process directly maps to the reference model description. Finally it gives a brief description of the objects that were developed and how they were used in the prototype.

#### **4.3.1 Integrated Development Environment Details**

The integrated development environment for the prototype was chosen based on its ability to allow extensive work on architectural implementation details while requiring minimal work to meet the requirements of the prototype.

- *WSO2 Enterprise Middleware*: The Carbon Infrastructure v3.1 by Web Services Oxygenated (WSO2) provides a software development kit targeted at low budget SOA-based development. All of the Java source code is provided for the SOA-based infrastructure allowing modifications as required. WSO2 also provides a set of basic services and tools that can be modified and reused as needed. WSO2 Carbon is based on Java OSGi technology which allows components to be dynamically installed, started, stopped, updated, and

uninstalled, as well as eliminating component version conflicts. In Carbon, this capability translates into a solid core of common middleware components, plus the ability to add components for specific features needed to solve a specific enterprise scenario. The core set of components in WSO2 Carbon provides WSO2 middleware products with a consistent set of management, security, clustering, logging, statistics, tracing, throttling, caching, and other capabilities as well as a management user interface framework. Central to these components is WSO2's SOA and Web Services engine. Add-in components encapsulate major types of functionality. A unified graphical management console can deploy, manage, and view services, processes, process instances, and statistics across the whole platform, comprising of different products. As each runtime component is added, associated management components are added to the user interface. With a simple front-end/back-end separation between the user interface and the runtime, all capabilities can be controlled through a remote WSO2 Carbon user interface, or through a clean Web Services interface.

- *Windows XP*: The Windows operating system was chosen as a platform for the implementation because many SOA-based military simulation and C2 federations are currently built for Windows. Furthermore, the WSO2 Carbon Infrastructure runs natively on Windows.
- *Eclipse 3.1*: Eclipse was used as the development environment for the implementation. It was used to manipulate and build the WSO2 Carbon



Infrastructure, implement the governance reference model, and create all the SOA layers for the prototype.

- *Apache Software License 2.0*: The SOA layers for the prototype include components available under the Apache open-source software license.
- *Hardware*: The hardware used to create and test the implementation was a Dell Latitude E6400 with a Core 2 Duo 2.53 GHz - 4 GB Ram - 250 GB HDD.

#### 4.3.2 Revised Governance Reference Model Implementation

The revised governance reference model was implemented according to the model description, specifications, and diagrams provided in Phase II. In table 14, each use case thread is interwoven with one or more of the three stages, and mapped to one or more Business Process Models (BPMs).

Table 14: Governance Reference Model Implementation Matrix

Stage	Threads	BPM
Realization of Data Service Governance	<ul style="list-style-type: none"> <li>• Data Service Policies and Standards</li> <li>• Data Service Processes and Procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Data Services Server</li> </ul>
Execution of Data Service Governance	<ul style="list-style-type: none"> <li>• Data Service Security Rules Governance</li> <li>• Data Service Policies and Standards</li> <li>• Data Service Processes and Procedures</li> <li>• Data Service Roles and Responsibilities Governance</li> </ul>	<ul style="list-style-type: none"> <li>• Governance Registry</li> <li>• Web Services Application Server</li> <li>• Business Process Server</li> </ul>
Enforcement of Data Service Governance	<ul style="list-style-type: none"> <li>• Data Service Security Rules Governance</li> <li>• Data Service Policies and Standards</li> <li>• Data Service Processes and Procedures</li> <li>• Data Service Metrics Governance</li> <li>• Data Service Behaviors Governance</li> </ul>	<ul style="list-style-type: none"> <li>• Security Server</li> <li>• Enterprise Service Bus</li> </ul>

The following sections further describe the BPMs used to drive the prototype's architectural design and implementation.

- *Data Services Server*: The Data Services Server augments SOA development efforts by providing a platform for creating and hosting data services based on identified policies and standards, and defined processes and procedures. Data services are essentially web services that provide access to data stored in heterogeneous data stores, thus enabling integration of data into business processes, applications, and any service in general (WSO2, 2009).

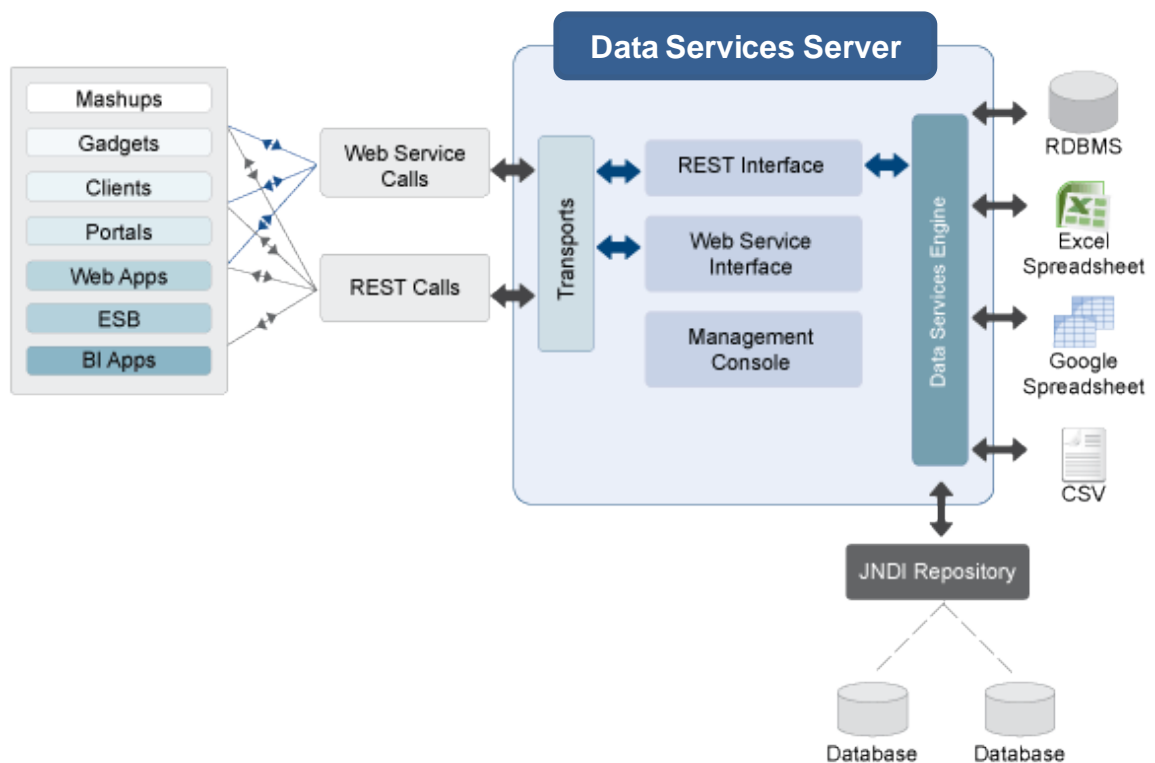


Figure 15: Data Services Server Business Process Model

- *Governance Registry*: As SOA adoption grows in an enterprise, SOA resources such as processes and policies must be securely managed. The Governance Registry addresses both design-time and runtime governance scenarios, to ensure compliance with organization standards. It allows enterprise architects and developers to monitor the services being created and used within an SOA. Governance Registry includes metadata repository, full versioning, lifecycle management, a model for establishing users/roles/permissions, and social features such as tagging, rating, and comments. Furthermore, the Governance Registry integrates with architecture layers to collect metadata about services, centralizes policy metadata, and manages dependencies. The Governance Registry connects SOA infrastructure with the people, processes, and policies essential to an effective SOA environment (WSO2, 2009).

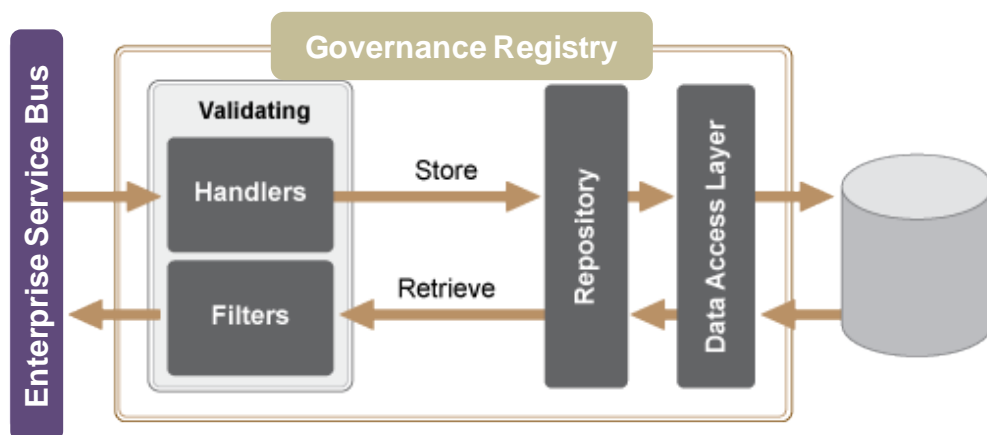


Figure 16: Governance Registry Business Process Model

- *Web Services Application Server Layer*: The Web Services Application Server (WSAS) is a Web services engine based on Apache Axis2. WSAS provides a secure, transactional and reliable runtime to create, consume, deploy and manage Web services in an SOA environment. WSAS includes functions that support clustering and high availability, Eclipse IDE integration, and full support for key web-service standards (WSO2, 2009).

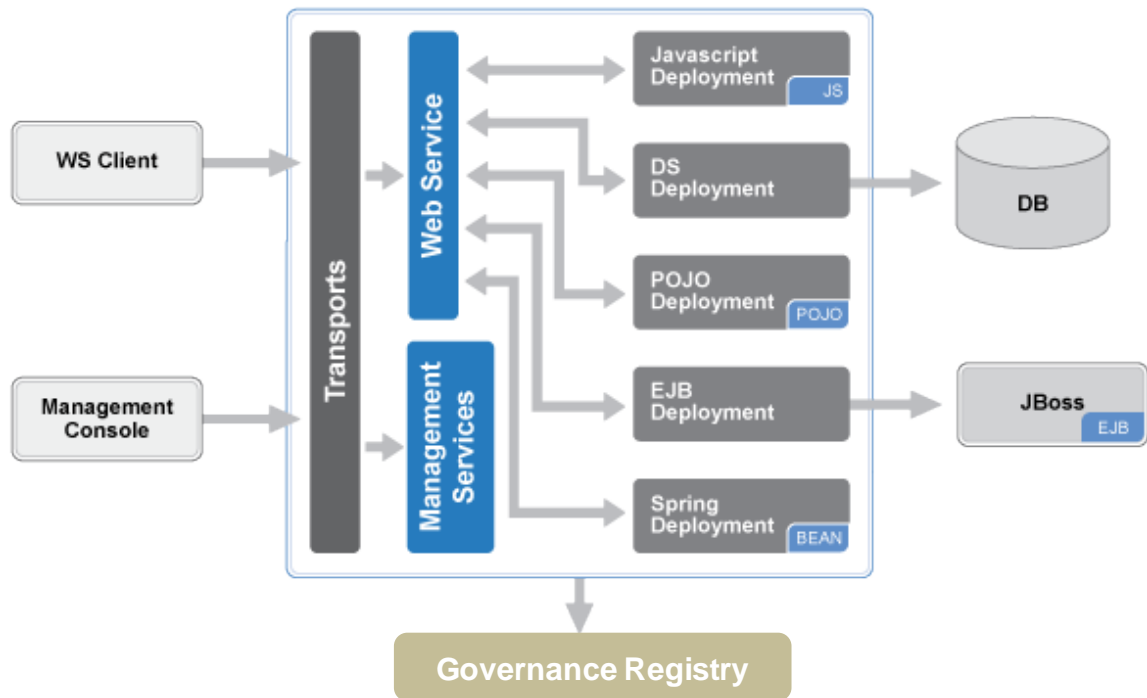


Figure 17: Web Services Application Server Business Process Model

- *Business Process Server*: The Business Process Server is a server that executes business processes written using the WS-BPEL standard. Powered by Apache ODE, it contains a Web-based graphical console to deploy, manage and view processes in addition to managing and viewing process instances (WSO2, 2009).

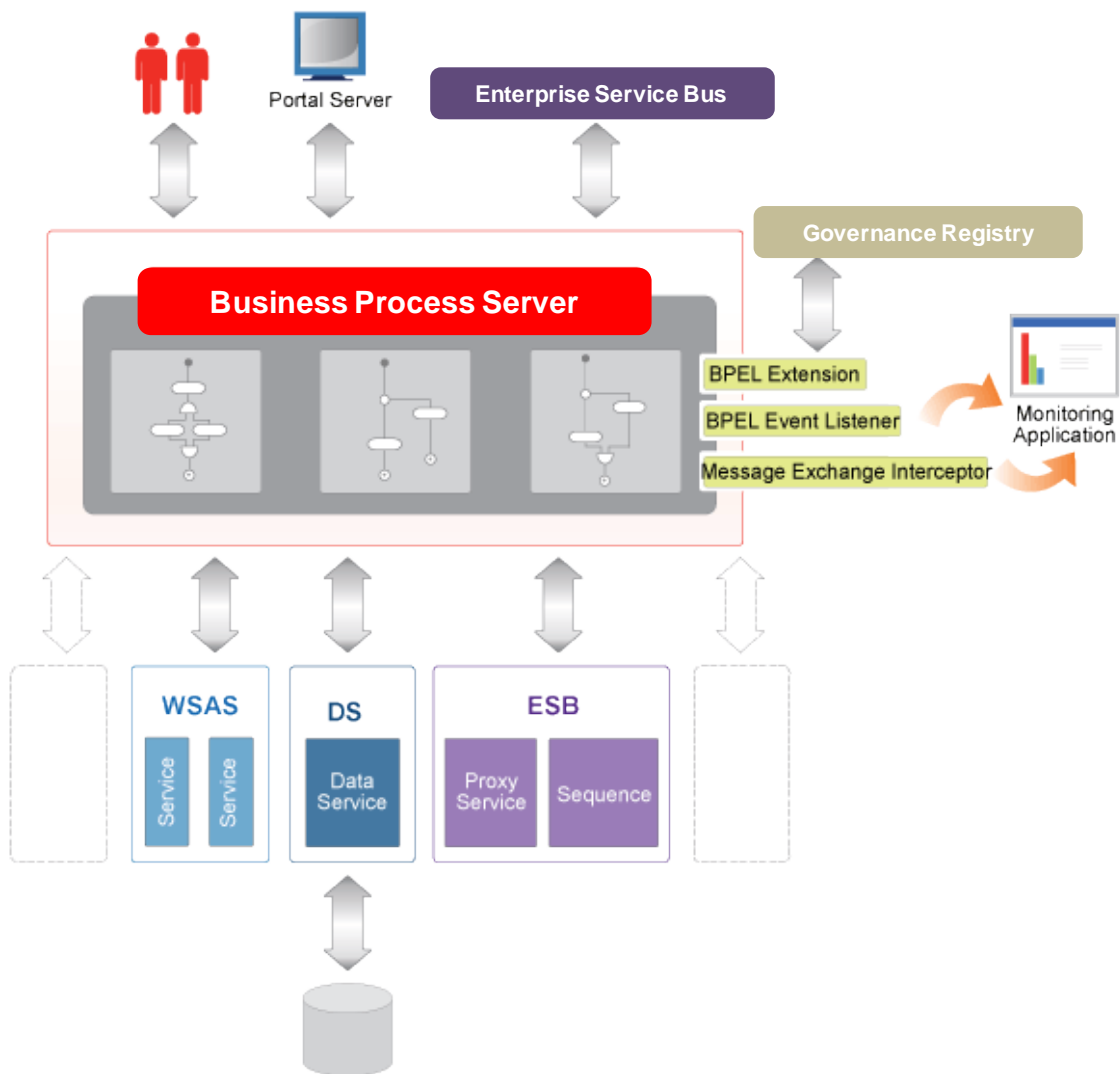


Figure 18: Business Process Server Business Process Model

- *Security Server Layer*: The Security Server is an identity and entitlement management server. It supports authentication and integrates into existing user stores such as LDAP or Active Directory, and supports multi-factor authentication. The Security Server helps build secured SOA. As SOA adoption grows in an organization, SOA resources such as processes and policies must be securely managed. The Security Server enables data service developers to improve SOA governance by guaranteeing secure online interactions within and outside of an SOA (WSO2, 2009).

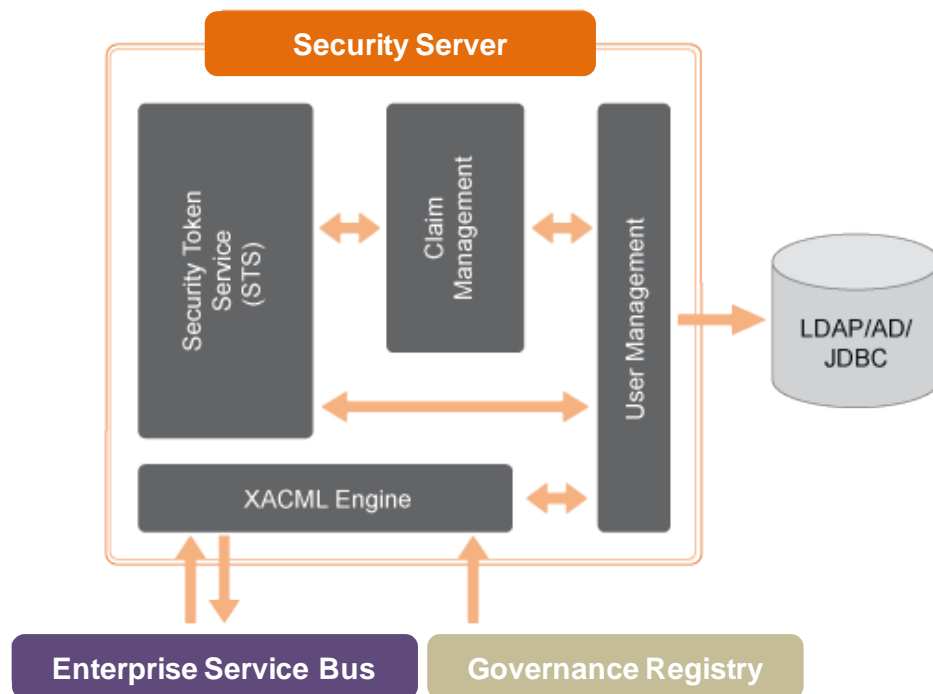


Figure 19: Security Server Business Process Model

- Enterprise Service Bus*: Within an SOA, services need to be loosely connected together. Traditional approaches to enterprise integration make it difficult for IT to adapt to changes in policies, business requirements or new technologies. The Enterprise Service Bus (ESB) supports monitoring, management and virtualization of existing service interactions. The graphical pipeline editor and the XML-based configuration language support complex flows without dropping down to a full programming language for common tasks (WSO2, 2009).

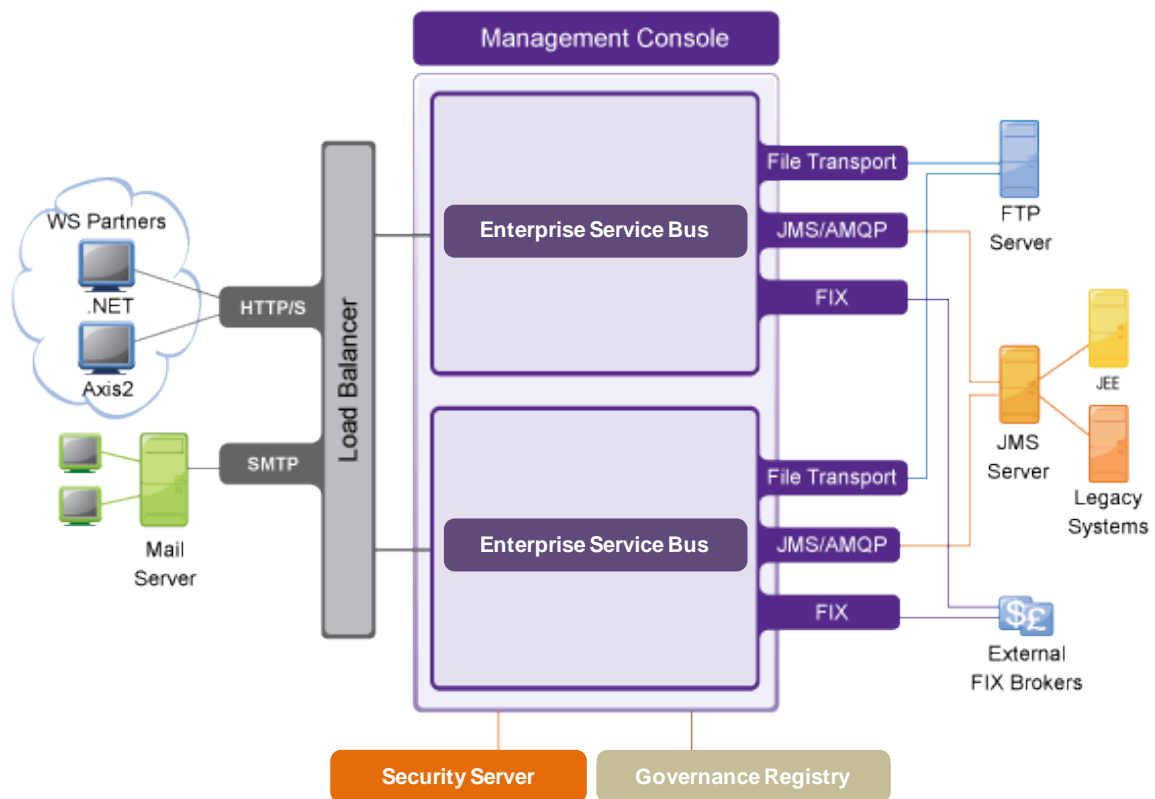


Figure 20: Enterprise Service Bus Business Process Model

### 4.3.3 Prototype Implementation

The prototype is a Governance-oriented SOA-based application implemented using web-services technology. The implementation is driven by the architecture described in Appendix E. In table 15, each graphical user interface console is mapped to a BPM. The following screenshots illustrate the graphical user interface of the prototype.

Table 15: Prototype Implementation Matrix

Stage	Threads	BPM	GUI Console
Realization of Data Service Governance	<ul style="list-style-type: none"><li>• Data Service Policies and Standards</li><li>• Data Service Processes and Procedures</li></ul>	<ul style="list-style-type: none"><li>• Data Services Server</li></ul>	<ul style="list-style-type: none"><li>• Data Services Console</li></ul>
Execution of Data Service Governance	<ul style="list-style-type: none"><li>• Data Service Security Rules Governance</li><li>• Data Service Policies and Standards</li><li>• Data Service Processes and Procedures</li><li>• Data Service Roles and Responsibilities Governance</li></ul>	<ul style="list-style-type: none"><li>• Governance Registry</li><li>• Web Services Application Server</li><li>• Business Process Server</li></ul>	<ul style="list-style-type: none"><li>• Governance Management Console</li><li>• Roles and Responsibilities Console</li></ul>
Enforcement of Data Service Governance	<ul style="list-style-type: none"><li>• Data Service Security Rules Governance</li><li>• Data Service Policies and Standards</li><li>• Data Service Processes and Procedures</li><li>• Data Service Metrics Governance</li><li>• Data Service Behaviors Governance</li></ul>	<ul style="list-style-type: none"><li>• Security Server</li><li>• Enterprise Service Bus</li></ul>	<ul style="list-style-type: none"><li>• Security Console</li><li>• Metrics Console</li><li>• Registry and Behaviors Console</li></ul>

Screenshots include:

- Data Services Console
- Governance Management Console



- Roles and Responsibilities Console
- Security Console
- Metrics Console
- Registry and Behaviors Console

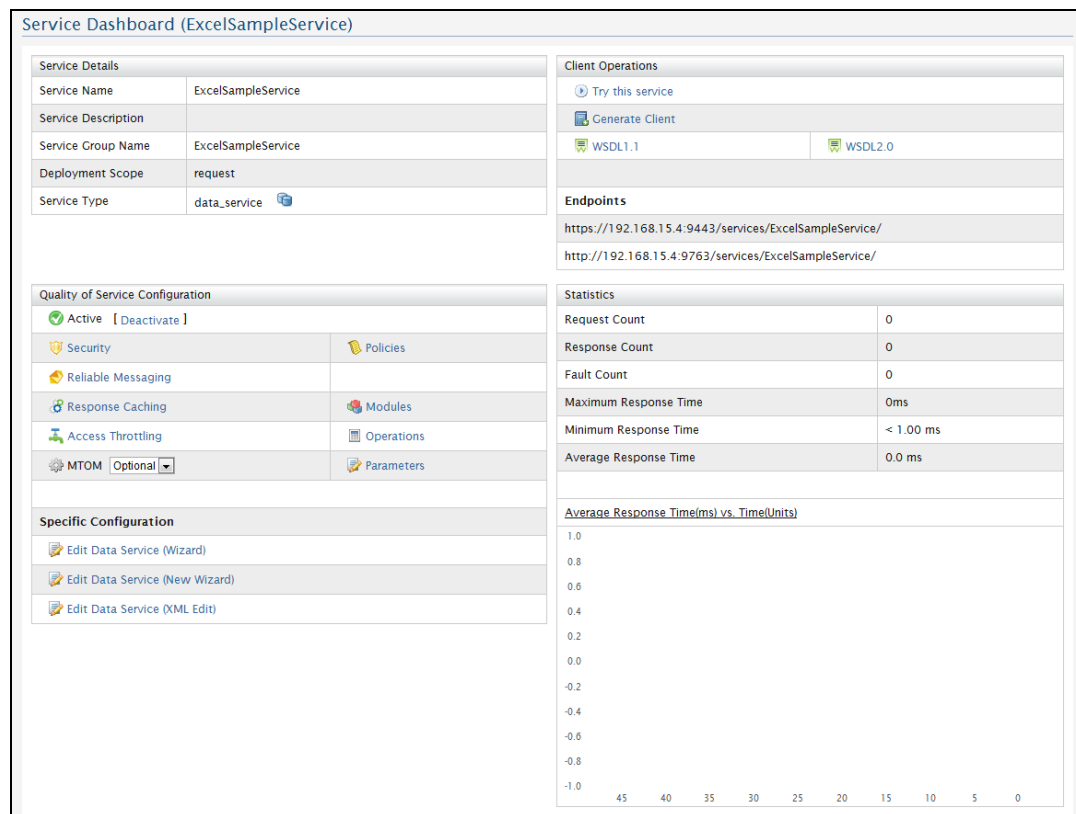


Figure 21: Data Service Console

The Data Service Console (figure 21) was built based on the following reference model stage, threads, and BPM:

- Stage: Realization of Data Service Governance
- Thread: Data Service Policies and Standards Governance

- Thread: Data Service Processes and Procedures Governance
- BPM: Data Services Server

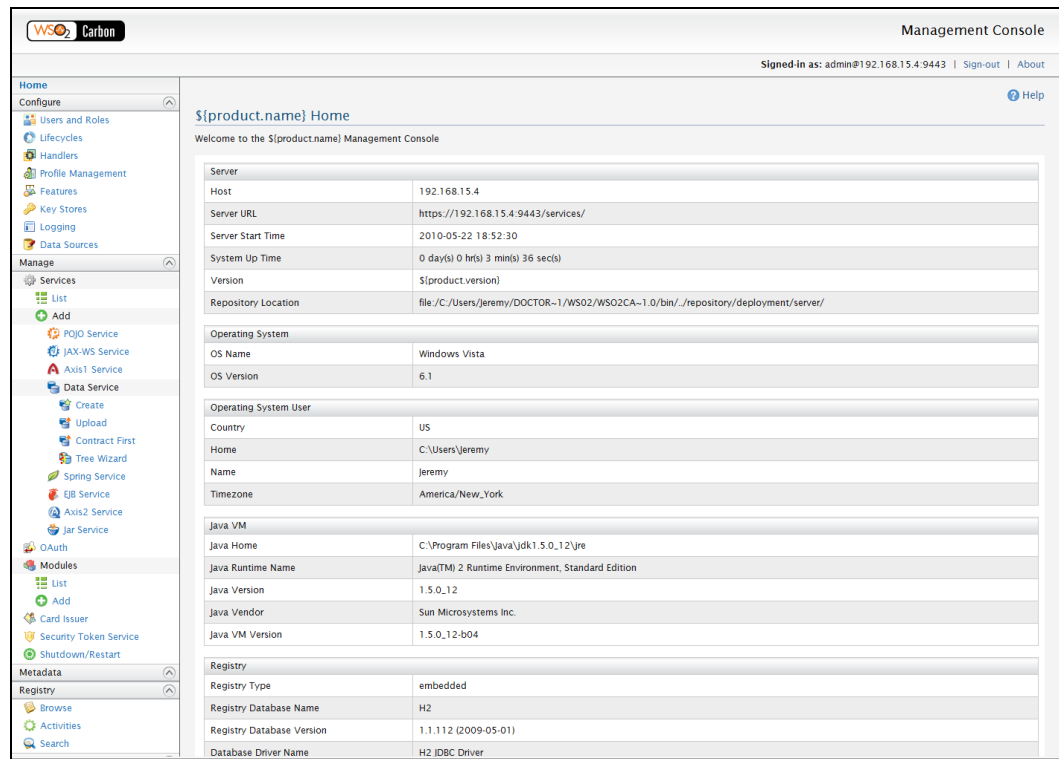


Figure 22: Governance Management Console


The Governance Management Console (figure 22) was built based on the following reference model stage, threads, and BPMs:

- Stage: Execution of Data Service Governance
- Thread: Data Service Security Rules Governance
- Thread: Data Service Policies and Standards
- Thread: Data Service Processes and Procedures

- BPM: Governance Registry
- BPM: Web Services Application Server
- BPM: Business Process Server

### Users

Enter user name pattern (\* for all)

 [Add New User](#)


 [Bulk Import Users](#)

Figure 23: Roles and Responsibilities Console - Users




Roles		
Name	Type	Actions
admin	Internal	 <a href="#">Users</a>
everyone	Internal	 <a href="#">Permissions</a>
 <a href="#">Add New Role</a>		

Figure 24: Roles and Responsibilities Console – Roles

**Add New Profile**

User Profile

Profile Name *	Data Service Sponsor
Profile Configuration	default ▼
First Name *	Jeremy
Last Name *	Lanman
Organization	DoD
Address	123 Anywhere Street
Country	USA
Email *	jlanman@myemail.com
Telephone	123-456-7890
Mobile	324-567-8900
IM	jeremylanman
URL	www.anyurl.com

Figure 25: Roles and Responsibilities Console - Profiles

The Roles and Responsibilities Console (figures 23-25) was built based on the following reference model stage, threads, and BPMs:

- Stage: Execution of Data Service Governance
- Thread: Data Service Security Rules Governance
- Thread: Data Service Policies and Standards
- Thread: Data Service Processes and Procedures
- Thread: Data Service Roles and Responsibilities Governance
- BPM: Governance Registry
- BPM: Web Services Application Server
- BPM: Business Process Server

**Security for the service**

The service "ExcelSampleService" is not secured.

Enable Security?

Basic Scenarios	
1. <input type="radio"/>	UsernameToken Provides Authentication. Clients have Username Tokens
2. <input type="radio"/>	Non-repudiation Provides Authentication and Integrity. Clients have X509 certificates
3. <input type="radio"/>	Integrity Provides Integrity. Clients do not have X509 certificates
4. <input type="radio"/>	Confidentiality Provides Confidentiality. Clients do not have X509 certificates

Advanced Scenarios	
5. <input type="radio"/>	Sign and encrypt - X509 Authentication Provides Authentication, Integrity and Confidentiality. Clients have X509 certificates
6. <input type="radio"/>	Sign and Encrypt - Anonymous clients Provides Integrity and Confidentiality.
7. <input type="radio"/>	Encrypt only - Username Token Authentication Provides Authentication and Confidentiality. Clients have Username Tokens
8. <input type="radio"/>	Sign and Encrypt - Username Token Authentication Provides Authentication, Integrity and Confidentiality. Clients have Username Tokens
9. <input type="radio"/>	SecureConversation - Sign only - Service as STS - Bootstrap policy - Sign and Encrypt , X509 Authentication Provides Authentication and Integrity. Multiple message exchange. Clients have X509 certificates.
10. <input type="radio"/>	SecureConversation - Encrypt only - Service as STS - Bootstrap policy - Sign and Encrypt , X509 Authentication Provides Confidentiality. Multiple message exchange. Clients have X509 certificates.
11. <input type="radio"/>	SecureConversation - Sign and Encrypt - Service as STS - Bootstrap policy - Sign and Encrypt , X509 Authentication Provides Authentication, Integrity and Confidentiality. Multiple message exchange. Clients have X509 certificates.
12. <input type="radio"/>	SecureConversation - Sign Only - Service as STS - Bootstrap policy - Sign and Encrypt , Anonymous clients Provides Integrity. Multiple message exchange.
13. <input type="radio"/>	SecureConversation - Sign and Encrypt - Service as STS - Bootstrap policy - Sign and Encrypt , Anonymous clients Provides Integrity and Confidentiality. Multiple message exchange.
14. <input type="radio"/>	SecureConversation - Encrypt Only - Service as STS - Bootstrap policy - Sign and Encrypt , Username Token Authentication Provides Authentication and Confidentiality. Multiple message exchange. Clients have Username Tokens.
15. <input type="radio"/>	SecureConversation - Sign and Encrypt - Service as STS - Bootstrap policy - Sign and Encrypt , Username Token Authentication Provides Authentication Integrity and Confidentiality. Multiple message exchange. Clients have Username Tokens.

Figure 26: Security Console

The Security Console (figure 26) was built based on the following reference model stage, threads, and BPMs:

- Stage: Enforcement of Data Service Governance
- Thread: Data Service Security Rules Governance
- Thread: Data Service Policies and Standards
- Thread: Data Service Processes and Procedures
- Thread: Data Service Metrics Governance
- Thread: Data Service Behaviors Governance
- BPM: Security Server
- BPM: Enterprise Service Bus

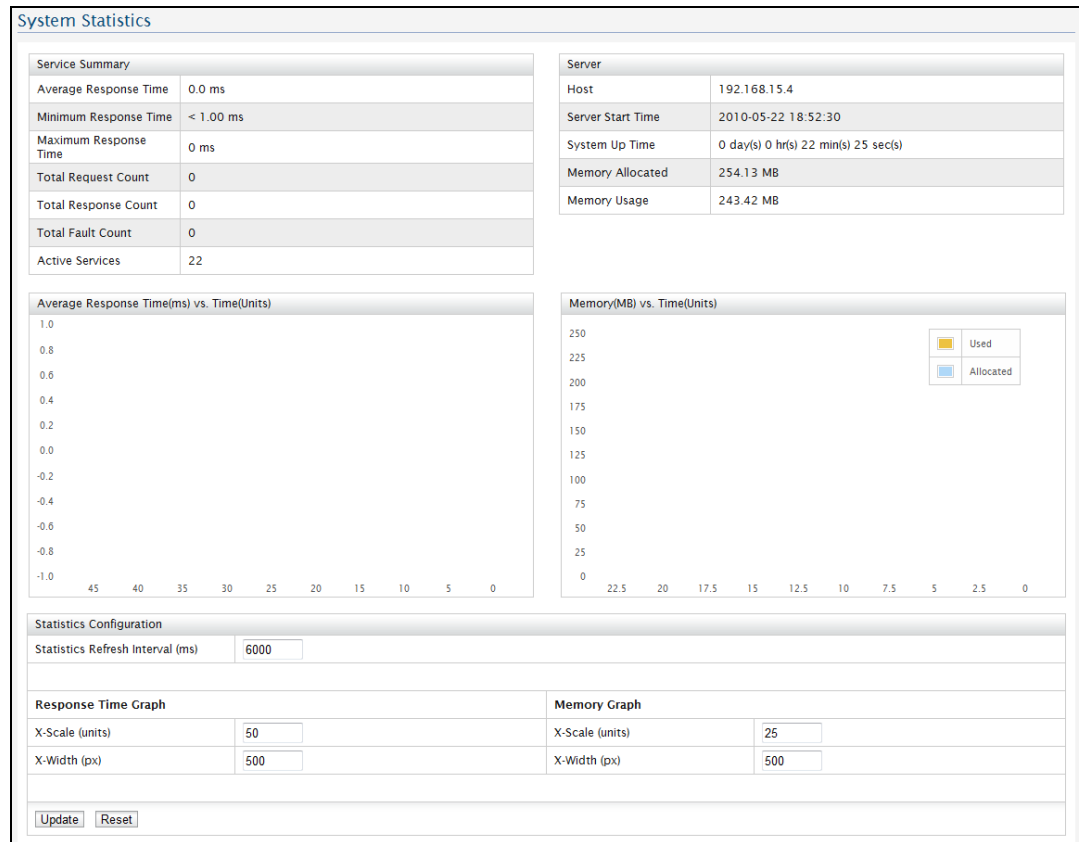


Figure 27: Metrics Console

The Metrics Console (figure 27) was built based on the following reference model stage, threads, and BPMs:

- Stage: Enforcement of Data Service Governance
- Thread: Data Service Policies and Standards
- Thread: Data Service Processes and Procedures
- Thread: Data Service Metrics Governance
- BPM: Enterprise Service Bus

**Browse**

Root [./system/governance](#)

**Metadata**

**Properties**

**Entries**

[Add Resource](#)  
[Add Collection](#)  
[Create Link](#)

**Add Resource**

Method: [Upload content from file](#)

Upload Content From File

File:  [Browse...](#)  
Give the path of a file to fetch content (xml,wsdl,jar etc..)

Name:

Media type:

Description:

[Add](#) [Cancel](#)

Name	Created On	Author
<a href="#">services</a> <a href="#">Info</a> <a href="#">Actions</a>	18 May	wso2.system..

**Permissions**

New Role Permissions

Role: [everyone](#) Action: [-Select-](#) ☒ Allow ☐ Deny

[Add Permission](#)

Defined Role Permissions

Role	Read		Write		Delete		Authorize	
	Allow	Deny	Allow	Deny	Allow	Deny	Allow	Deny
everyone	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

[Apply All Permissions](#)

**Search**

[Search](#)

**Dependencies**

[Add Dependency](#)  
 No dependencies on this entry yet.

**Associations**

[Add Association](#)  
 No associations on this entry yet.

**Lifecycle**

[Add Lifecycle](#)  
 No lifecycles on this entry yet.

**Comments**

[Add Comment](#) [Feed](#)  
 No comments on this entry yet

**Ratings**

My Rating: ☐ ☐ ☐ ☐ ☐

Rating: ☐ ☐ ☐ ☐ ☐ (3.0)

**Subscriptions**

[Add Subscription](#)  
 No subscriptions for events of this entry.

**Tags**

[Add New Tag](#)  
 No tags on this entry yet

Figure 28: Registry and Behaviors Console

The Registry and Behaviors Console (figure 28) was built based on the following reference model stage, threads, and BPMs:

- Stage: Enforcement of Data Service Governance
- Thread: Data Service Metrics Governance
- Thread: Data Service Behaviors Governance
- BPM: Enterprise Service Bus

A full description of the prototype’s architectural design can be found in Appendix E.

#### **4.4 Phase IV: Evaluation, Verification, and Validation of Governance Reference**

##### **Model and Prototype**

The Evaluation phase documents whether the original research objectives have been realized. The prototype is first verified against its original requirements, and then the design strategies developed in Phase II are evaluated for impact on the revised governance reference model and the prototype. Finally the research is validated by assessing the implementation details of the prototype against the original objectives for the revised governance reference model.

##### **4.4.1 Verification of the Prototype**

The prototype was verified by three Subject Matter Experts (SMEs) against each of its requirements as shown in table 16. The *Type* field specifies the requirements as derived from a best practice or structured interview question. The *Reference / Category* field specifies a specific reference in literature or to a specific structured questionnaire category. The *Verified* field documents the “Yes” or “No” answer provided by SMEs when asked if the proof-of-concept prototype satisfied the governance reference model goals. The *Explanation* field provides an objective statement or fact that supports the SME verification.



Table 16: Prototype Requirements Verification

No.	Requirement	Type	Reference / Category	Verified? (Yes/No)		
				SME A	SME B	SME C
Functional Requirements for Prototype						
1	Prototype shall be a SOA-based internet application	Best Practice	OASIS, 2006	Yes	Yes	Yes
<b>Explanation:</b> The prototype was built to evaluator specifications using Carbon Infrastructure v3.1 by Web Services Oxygenated (WSO2). Carbon provided a software development kit targeted at low budget SOA-based development. The resulting code can be found at <a href="http://www.ws02.org/products/carbon">http://www.ws02.org/products/carbon</a> .						
2	Prototype shall have a Graphical User Interface	Best Practice	Gartner, 2007; OASIS, 2006	Yes	Yes	Yes
<b>Explanation:</b> Eclipse 3.1 provided a software development kit that includes an API for developing a web-based graphical user interface that can port to the Carbon Infrastructure and link to available services. The API can be extended to include custom consoles and services. The SDK can be found at <a href="http://www.eclipse.org">http://www.eclipse.org</a> .						
3	Prototype shall include policies, processes, tools, and standards required to produce a common data initialization product	Structured Interview	Governance Category; Business Model Category	Yes	Yes	Yes
<b>Explanation:</b> The data services created using the prototype included policies for WS-Security in the Security console and WS-Policy for Web Services Data Language (WSDL) in the Data Services console. The data services, standards, and relative documents were stored in the Registry console to allow for reusability. Processes were implemented using the Lifecycle module within the SOA Management console. The WS-Security, WS-Policy, and WSDL policies can be found at <a href="http://www.oasis-open.org">http://www.oasis-open.org</a> .						
4	Prototype shall include a registry to store common data services, standards, policies, and documentation	Best Practice	ZapThink, 2006; Gartner, 2007; IBM, 2006	Yes	Yes	Yes
<b>Explanation:</b> The Registry console within the prototype provided a mechanism for storing reusable products. The Data Services console contained relevant common data initialization services that may be used or modified to build data products. The Metrics console provided Quality of Service (QoS) metrics for data services.						

No.	Requirement	Type	Reference / Category	Verified? (Yes/No)		
				SME A	SME B	SME C
Functional Requirements for Prototype						
5	Prototype shall be based on governance reference model and link governance activities to appropriate policies, processes, tools, metrics, and standards	Structured Interview	SOA Category; Governance Category	Yes	Yes	Yes
Explanation: The prototype had been documented in the Phase III Results to conform to the governance reference model and architectural description and specification documented in Phase II Results.						
6	Prototype shall utilize web services for searching, discovering, and manipulating data	Best Practice	ZapThink, 2006; Gartner, 2007; IBM, 2006; Oracle, 2008	Yes	Yes	Yes
Explanation: The Carbon Infrastructure provided the web-service wrapper for data service applications.						
7	Prototype shall allow user to dynamically create, search, and download a common data service in registry	Best Practice	ZapThink, 2006; Gartner, 2007; IBM, 2006; Oracle, 2008	Yes	Yes	Yes
Explanation: The Registry console and Data Services console provided web services for creating, searching, and downloading data services from the registry. These web services were designed using the Carbon software development kit found at <a href="http://www.ws02.org/products/carbon">http://www.ws02.org/products/carbon</a> .						
8	Prototype shall allow user to configure common data into common initialization formats (XML, CSV, XLS)	Structured Interview	Business Model Category	Yes	Yes	Yes
Explanation: The Registry console and Data Services console provided automatic configuration management and tools for migration of data services to WSDL standard updates. The Management console provided logistical information and access to common SOA and data service tools. Data services that are created can be configured into XML, CSV, or XLS formats.						
9	Prototype shall allow user to dynamically update reference model components (policies, rules, standards, etc.)	Structured Interview	SOA Category; Business Model Category	Yes	Yes	Yes

No.	Requirement	Type	Reference / Category	Verified? (Yes/No)		
				SME A	SME B	SME C
<b>Explanation:</b> The Registry console allowed for policies, rules, and standards to be updated dynamically using web services.						
<i>Development Time Requirements for Data Services</i>						
10	Development Time to discover required standards and policies shall be collected for data service	Best Practice	Menasce, 2007; Gartner, 2007; ZapThink, 2006	Yes	Yes	Yes
<b>Explanation:</b> The development time to discover standards and policies was collected during the application-oriented evaluation (Menasce, 2007).						
11	Development Time needed to identify required run-time metrics shall be collected for data service	Best Practice	Menasce, 2007; Choi, 2008; Gartner, 2007; OASIS, 2006	Yes	Yes	Yes
<b>Explanation:</b> The development time to identify run-time metrics was collected during the application-oriented evaluation. The metrics included QoS measures for performance, availability, and reliability (Menasce, 2007; Choi, 2008).						
12	Development Time needed to assign roles and responsibilities shall be collected for data service	Best Practice	Menasce, 2007; Gartner, 2007; OASIS, 2006	Yes	Yes	Yes
<b>Explanation:</b> The Roles and Responsibilities console allowed service developers to identify users for specific roles and set credentials for subscription, publication, usage authorization and sharing of data services. The Registry console allowed sharing of data services; as well as, allowed SMEs to evaluate and rate the quality of data services and products. The development time needed to identify and assign roles and responsibilities was collected during the application-oriented evaluation (Menasce, 2007; Choi, 2008).						
<i>Development Cost Requirement for Data Services</i>						
13	Development Cost associated with the data service development shall be less than baseline data development cost	Literature Review	Black, 2006; Tolk, 2007; DoD CIO, 2006	Yes	Yes	Yes

No.	Requirement	Type	Reference / Category	Verified? (Yes/No)		
				SME A	SME B	SME C
<b>Explanation:</b> The baseline data development time includes weeks and sometimes months which can cost in the range of \$2,000-\$5,000 for a single, consolidated data set configured in a specific format (i.e. XML) (Black, 2006; Tolk, 2007, DoD CIO, 2006). The development time for a data service using the prototype and executing it to build a data set automatically was done in minutes. The cost was a fraction of the baseline (\$10-\$50); a significant cost savings.						
<i>Quality of Service (QoS) Requirements for Data Services</i>						
14	Availability metrics shall be collected for data service	Best Practice	Choi, 2008; Misic, 2000; Menasce, 2007	Yes	Yes	Yes
<b>Explanation:</b> Data Service Request Count (Availability) metrics were collected at run-time for the newly developed data services using the prototype (Menasce, 2007; Choi, 2008). The Metrics console was developed using Eclipse 3.1 and ported to the Carbon Infrastructure platform.						
15	Performance metrics shall be collected for data service	Best Practice	Choi, 2008; Misic, 2000; Menasce, 2007	Yes	Yes	Yes
<b>Explanation:</b> Data Service Average Response Time (Performance) metrics were collected at run-time for the newly developed data services using the prototype (Menasce, 2007; Choi, 2008). The Metrics console was developed using Eclipse 3.1 and ported to the Carbon Infrastructure platform.						
16	Reliability metrics shall be collected for data service	Best Practice	Choi, 2008; Misic, 2000; Menasce, 2007	Yes	Yes	Yes
<b>Explanation:</b> Data Service Response Count / Data Service Failure Count (Reliability) metrics were collected at run-time for the newly developed data services using the prototype (Menasce, 2007; Choi, 2008). The Metrics console was developed using Eclipse 3.1 and ported to the Carbon Infrastructure platform.						

#### 4.4.2 Application-oriented Evaluation Using Goal-Question-Metric Approach

Because the revised governance reference model was built based on a set of strategies developed from Subject Matter Expert (SME) input and organizational best practices, it is important that the implementation of the strategies be verified. Each strategy documented in Phase II can be verified by documenting its impact on the implementation of the governance reference model and the prototype using the GQM evaluation approach.

The SMEs that provided responses to the questionnaires were asked to evaluate the revised governance reference model and prototype, and provide the following metrics (table 17):

Table 17: GQM Metrics Key

Metric	Description
1	Time needed to discover required standards and policies (TS)
2	Time needed to identify required run-time metrics (TM)
3	Time needed to assign roles and responsibilities (TR)
4	Approximate costs associated with the data service development: $AC = ((TS + TM + TR) \times \text{average hourly rate})$
5	Availability: <ul style="list-style-type: none"><li>○ Data Service Request Count</li></ul>
6	Performance: <ul style="list-style-type: none"><li>○ Data Service Average Response Time</li></ul>
7	Reliability: <ul style="list-style-type: none"><li>○ Data Service Request Count / Data Service Failure Count</li></ul>

Table 18 describes the GQM metrics collected for three SMEs that provided responses to the questionnaire.

Table 18: GQM Metrics Collected During Subject Matter Expert Evaluation

<b>Metric</b>	<b>SME A</b>	<b>SME B</b>	<b>SME C</b>	<b>Average</b>
<b>1</b>	4.00 minutes	2.50 minutes	2.00 minutes	<b>2.80 minutes</b>
<b>2</b>	5.00 minutes	1.00 minute	2.25 minutes	<b>2.75 minutes</b>
<b>3</b>	8.00 minutes	6.00 minutes	12.00 minutes	<b>8.70 minutes</b>
<b>4</b>	0.28 hr x \$50 = \$14.00	0.16 hr x \$50 = \$8.00	0.27 hr x \$50 = \$13.50	<b>\$11.83</b>
<b>5</b>	10 / 10	10 / 10	10 / 10	<b>100%</b>
<b>6</b>	10.33 ms	4.50 ms	3.70 ms	<b>6.18 ms</b>
<b>7</b>	10 / 0 (100%)	10 / 0 (100%)	10 / 1 (90%)	<b>96.67%</b>

The last column describes the combined average of the three sets of metric data. The average time needed to discover required standards and policies was 2.80 minutes, the average time needed to identify required run-time metrics was 2.75 minutes, and the time needed to assign roles and responsibilities was 8.70 minutes. The average approximate cost associated with the data service development was \$11.83 per hour. The data service developed was available and executed 10 times for each SME. The average performance for the data service was 6.18 ms, and the average reliability was 96.67%.

Table 19 describes the baseline average metrics identified by SMEs and published references.

Table 19: Baseline Metrics Identified by References

<b>Metric</b>	<b>Baseline Average</b>	<b>Reference(s)</b>
<b>1</b>	600 minutes (10 hours)	SME interviews; Black, 2006; Carleton, 2006
<b>2</b>	240 minutes (4 hours)	SME interviews; Tolk, 2005
<b>3</b>	1,020 minutes (17 hours)	SME interviews; Black, 2006
<b>4</b>	31 hr x \$50 = \$1,550.00	SME interviews; CNNMoney.com
<b>5</b>	100%	SME interviews; Lenahan, 2005
<b>6</b>	2,774.70 ms	SME interviews; Choi, 2008; Lenahan, 2005
<b>7</b>	86.66%	SME interviews; Choi, 2008; Lenahan, 2005

The baseline average column describes the estimated average amount time for stakeholders to discover required policies and standards, identify required run-time metrics, and assign roles and responsibilities to service-like activity in current SOA-based environments for command and control systems. Also, the estimated average cost is determined based on the average salary (\$50 per hour) of a mid-level software engineer in the United States (CNNMoney.com, 2010). The baseline metrics for performance and reliability are derived from SME interview data and a documented case study for SOA-based command and control (Lenahan, 2005).

Table 20 compares the variance baseline average metrics and prototype average metrics collected during SME evaluation of the prototype.

Table 20: Baseline Average Metrics vs. Prototype Average Metrics Analysis

<b>Metric</b>	<b>Baseline Average</b>	<b>Prototype Average</b>	<b>Estimated Order of Magnitude</b>
<b>1</b>	600 minutes (10 hours)	2.80 minutes (0.046 hours)	$10^{-3}$
<b>2</b>	240 minutes (4 hours)	2.75 minutes (0.045 hours)	$10^{-3}$
<b>3</b>	1,020 minutes (17 hours)	8.70 minutes (0.145 hours)	$10^{-3}$
<b>4</b>	\$1,550.00	\$11.83	$10^{-3}$
<b>5</b>	100%	100%	$10^0$ or 1
<b>6</b>	2,774.70 ms	6.18 ms	$10^{-3}$
<b>7</b>	86.66%	96.67%	10%

The variance is interpreted below:

- *Time (TS)*: the prototype average for *TS* needed to discover required standards and policies is an estimated order of magnitude of  $10^{-3}$  faster than the baseline average. This means that the prototype time was a thousandth of the time required in the baseline average. The prototype provided the capability for stakeholders to

discover standards and policies in 2.80 minutes; whereas, in a SOA-based environment without formal governance, the average *TS* needed is 600 minutes.

- *Time (TM)*: the prototype average for *TM* needed to identify required run-time metrics is an estimated order of magnitude of  $10^{-3}$  faster than the baseline average. This means that the prototype time was a thousandth of the time required in the baseline average. The prototype provided the capability for stakeholders to identify required run-time metrics in 2.75 minutes; whereas, in a SOA-based environment without formal governance, the average *TM* is 240 minutes.
- *Time (TR)*: the prototype average for *TR* needed to assign roles and responsibilities is an estimated order of magnitude of  $10^{-3}$  faster than the baseline average. This means that the prototype time was a thousandth of the time required in the baseline average. The prototype provided the capability for stakeholders to assign roles and responsibilities in 8.70 minutes; whereas, in a SOA-based environment without formal governance, the average *TR* is 1,020 minutes.
- *Cost (AC)*: the prototype average for *AC* associated with the data service development shows greater cost effectiveness by an estimated order of magnitude of  $10^{-3}$ . This means that the prototype cost was a thousandth of the cost required in the baseline average. The prototype reduced the cost for creating a simple data service to \$11.83; whereas, in a SOA-based environment without formal governance, the average *AC* is \$1,550.00.
- *Availability*: the baseline average *Data Service Request Count* is 10 out of 10 executions. The prototype average for each execution instance of a data service is



10 out of 10 as well. Thus, the 100% availability or order of magnitude of 1 is maintained from baseline to prototype.

- *Performance*: the baseline average *Data Service Average Response Time* is 2,774.70 ms, and the prototype average is 6.18 ms. The prototype average indicates a reduction in the amount of time for a data service to respond when triggered that result in improved network performance. The estimated order of magnitude is  $10^{-3}$  faster than the baseline average. This means that the prototype performance was a thousandth of the time required in the baseline average.
- *Reliability*: the baseline average *Data Service Request Count / Data Service Failure Count* is 86.66%, and the prototype average is 96.67%. The estimated order of magnitude is a 10% improvement in reliability. The prototype, compared to a baseline SOA-based implementation without formal governance, provided greater reliability by having fewer data service failures. A data service failure could be attributed to the development of an incomplete data service that is missing governance structures (e.g. standards and policies).

#### **4.4.3 Validation of the Governance Reference Model**

In order to ensure that the governance reference model has met the original research objectives, it is necessary to show how the prototype has met those objectives. This is accomplished by ensuring that the prototype has met the reference modeling requirements specified in Phase III. Table 21 describes the original governance reference model goals and prototype requirements. The *Type* field specifies the goals and requirements as derived from a best practice or structured interview question. The

*Reference / Category* field specifies a specific reference in literature or to a specific structured questionnaire category. The *Validated* field documents the “Yes” or “No” answer provided by SMEs when asked if the proof-of-concept prototype satisfied the overall governance reference model goals. The *Explanation* field provides an objective statement or fact that supports the SME validation.

Table 21: Governance Reference Model Goals and Requirements Validation

No.	Governance Reference Model Goal	Prototype Requirement	Type	Reference / Category	Validated? (Yes/No)		
					SME A	SME B	SME C
1	The reference model will provide a generic platform for creating common data initialization services and products.	Prototype shall be documented to conform to the governance reference model and architectural description and specification created in Phase II.	Best Practice	OASIS, 2006; Gartner 2007	Yes	Yes	Yes
<b>Explanation:</b> The prototype had been documented in the Phase III Results to conform to the governance reference model and architectural description and specification documented in Phase II Results.							
2	The reference model will support reusable data services, tools, policies, processes, and standards	Prototype shall include policies and processes for at least the following: Security, and Service Description	Structured Interview	Governance Category; SOA Category	Yes	Yes	Yes
<b>Explanation:</b> The data services created using the prototype included policies for WS-Security in the Security console and WS-Policy for Web Services Data Language (WSDL) in the Data Services console. The data services, standards, and relative documents were stored in the Registry console to allow for reusability. Processes were implemented using the Lifecycle module within the SOA Management console.							
3	The reference model will provide common data consistency, verification, validation, and re-use.	Prototype shall incorporate common data initialization services and products	Structured Interview	Governance Category; Business Model Category	Yes	Yes	Yes
<b>Explanation:</b> The Registry console within the prototype provided a mechanism for storing reusable products. The Data Services console contained relevant common data initialization services that may be used or modified to build data products. The Metrics console provided QoS metrics for data services.							
4	The reference model will	Prototype shall provide data	Structured	SOA	Yes	Yes	Yes

No.	Governance Reference Model Goal	Prototype Requirement	Type	Reference / Category	Validated? (Yes/No)		
					SME A	SME B	SME C
	enable sharing of common data assets.	services to subscribed and authorized users.	Interview	Category; Governance Category			
<b>Explanation:</b> The Roles and Responsibilities console allowed service developers to identify users for specific roles and set credentials for subscription, publication, usage authorization and sharing of data services. The Registry console allowed sharing of data services; as well as, allowed stakeholders to evaluate and rate the quality of data services and products.							
5	The reference model will automate common data migration & change management.	Prototype shall incorporate a data registry for common data discovery, dissemination, and management.	Structured Interview	Governance Category; Business Model Category	Yes	Yes	Yes
<b>Explanation:</b> The Registry console and Data Services console provided automatic configuration management and tools for migration of data services to WSDL standard updates. The Management console provided developers' logistical information and access to common SOA and data service tools.							

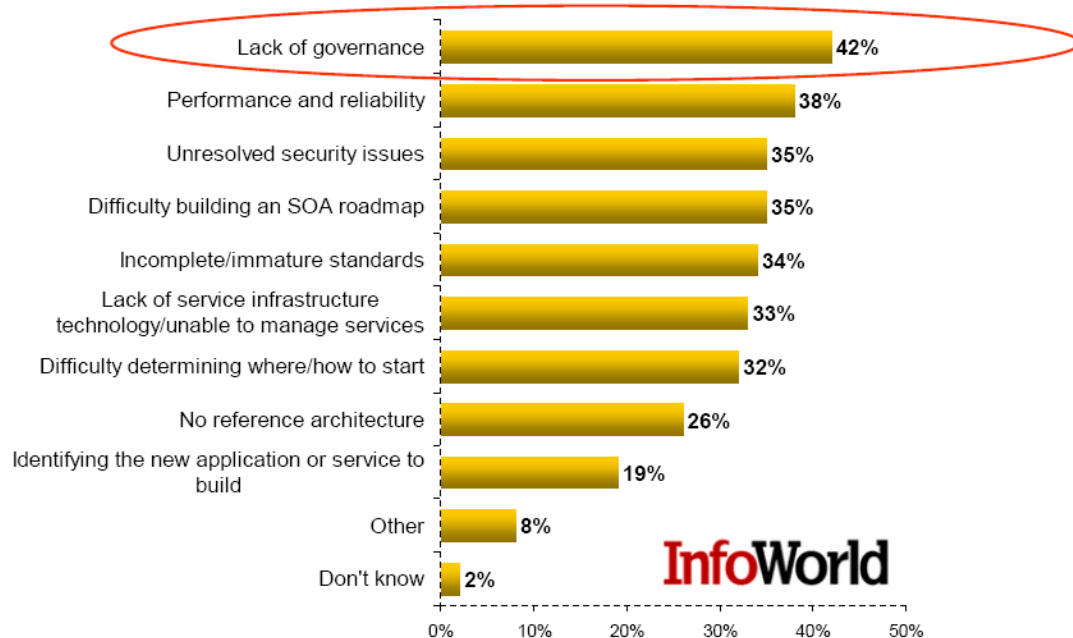
## **5.0 CONCLUSION AND FUTURE RESEARCH DIRECTIONS**

This chapter draws to conclusion the research work and documented results of the previous chapters. A summary of the results of the completed research and its original contributions are presented. A set of limitations of the governance reference model as implemented in this research are presented and discussed. Finally a number of topics are identified for future research efforts in the SOA-based governance of common data initialization for military simulation and command and control federation systems domain.

### **5.1 Background Refresh**

This section provides a summary of the literature that provided motivation for this research. As mentioned in Chapter 1, industry and government sectors implementing SOAs have found that governance is one of the most important topics associated with achieving a successful Network-Centric Environment. An InfoWorld study released in July 2006 (see figure 29) determined that 42% of the projects examined identified a lack of governance to be the largest factor inhibiting SOA adoption (InfoWorld, 2006).

## Factors that inhibit SOA adoption



Source: InfoWorld Research Report: SOA July 2006

Figure 29: InfoWorld study describing factors that inhibit SOA adoption

### 5.2 Flow of Research

This section provides a summary of the research flow that directed data input and documented research products. As depicted in figure 30, the first step was the identification of organizational best practices that lead to the published *initial* conceptual governance reference model.

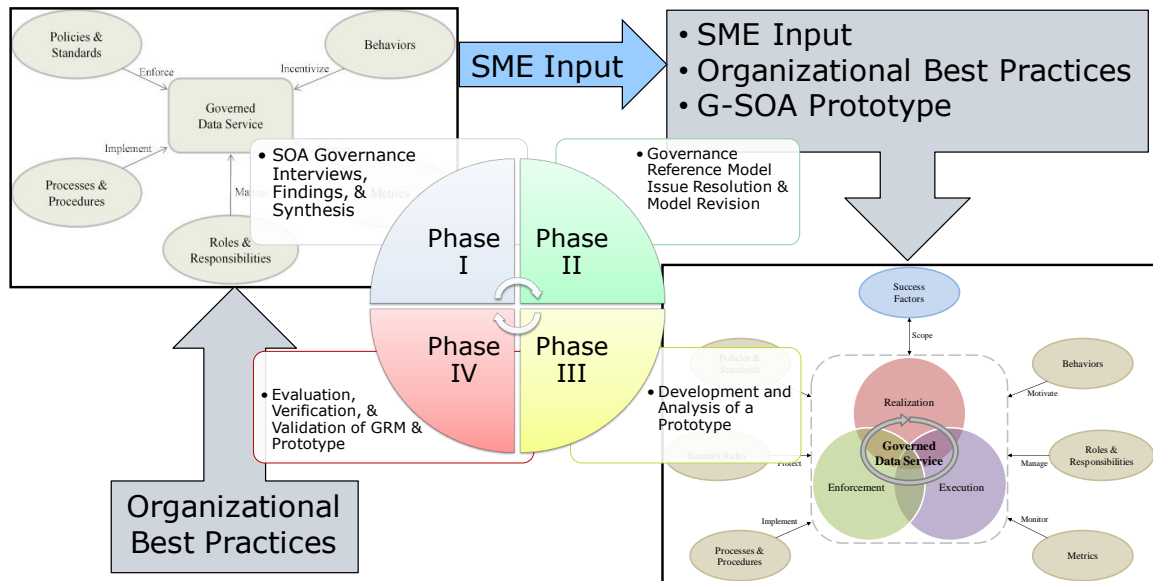


Figure 30: Flow of Research Diagram

Phase I of the research concept and methodology process was started. The *initial* conceptual governance reference model was integrated into a questionnaire presented to subject matter experts (SMEs) for input. SME input and organizational best practices were synthesized in Phase II which produced a list of factors, issues, and strategies. Strategies drove the development of the *revised* governance reference model which included a first-order decomposition. In Phase III, the *revised* governance reference model was used to drive the development and analysis of a prototype. In Phase IV, the *revised* governance reference model and prototype were evaluated, verified, and validated by SMEs.

### 5.3 Summary of Findings

This section provides a summary of the findings obtained in each phase of the research and documents that the research objective has been attained.

Phase I represented an analysis of the problem space relating to common data initialization of SOA-based military simulation and C2 systems. Nine experts were interviewed in the domains of service oriented architecture, governance, business models and data initialization. From these interviews a list of twenty-five factors were extracted which represented the set of highest risk items that would face a governance reference model for SOA-based common data initialization of military simulation and C2 systems. The isolated factors were categorized into ten fundamental issues that the governance reference model needed to address.

Phase II involved the design and documentation of the *revised* governance reference model (figure 31) for SOA-based common data initialization of military simulation and C2 systems.



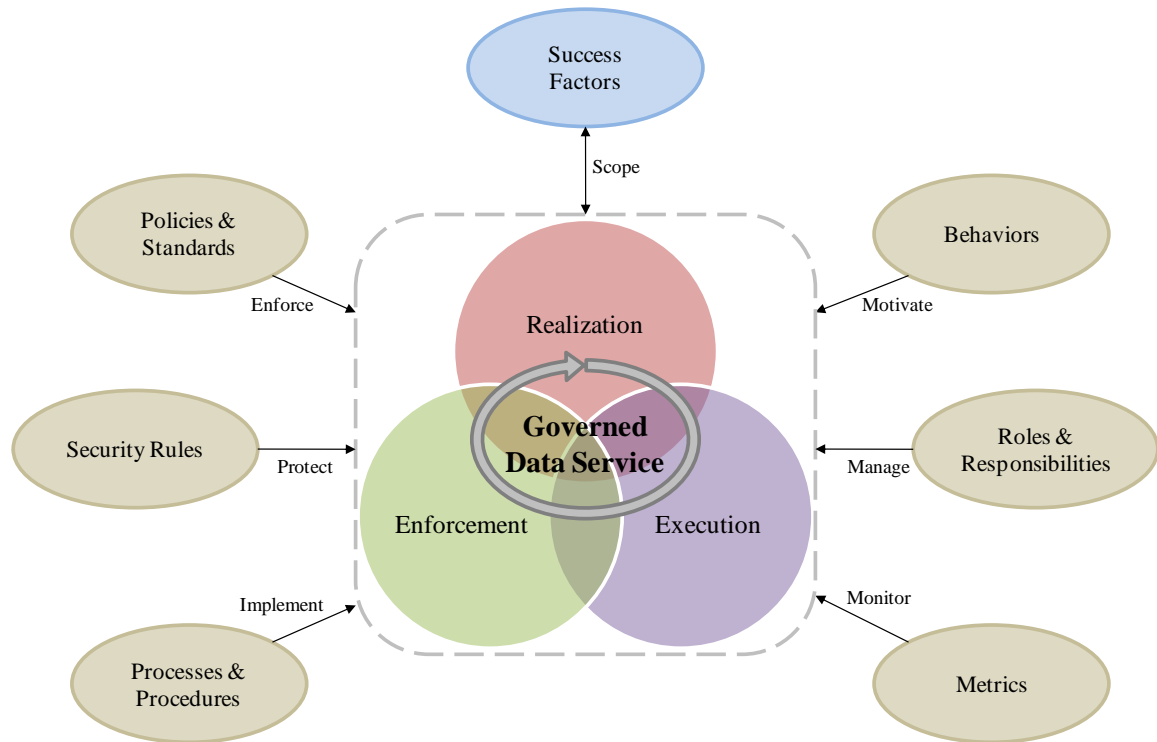


Figure 31: High Level Governance Reference Model

For each issue identified in Phase I a corresponding solution was developed whose purpose was to resolve the issue and help mitigate its associated factors. Each solution was supported by one or more specific design strategies that directly impacted the design and implementation of the governance reference model. The governance reference model developmental process methodology was developed to guide development of the governance reference model, and drive the design of the governance-oriented Service-oriented architecture. Generic development of SOA governance can be associated with three abstract stages: realization, execution, and enforcement. Their assigned responsibilities are listed below.

- *Realization*: This stage provides the underlying core governance structure for applying governance in an environment. It is responsible for defining governance and a governance body, establishing policies and processes, and the overall governance structure for stakeholders.
- *Execution*: This stage provides the operational structure for managing the service lifecycle.
- *Enforcement*: This stage provides the conformance structure for ensuring the adherence of a service to the governance model.

Seven generic use case threads that drive successful governance was also identified: success factors, security rules, policies and standards, processes and procedures, roles and responsibilities, metrics, and behaviors. Their assigned responsibilities are listed below.

- *Success Factors*: This thread provides a bidirectional scoping structure for a service and organization.
- *Security Rules*: This thread provides a protection structure for a service.
- *Policies and Standards*: This thread provides an enforcement structure for a service.
- *Processes and Procedures*: This thread provides an implementation structure for a service.
- *Roles and Responsibilities*: This thread provides a management structure for a service.
- *Metrics*: This thread provides a monitoring structure for a service.

- *Behaviors*: This thread provides a motivation structure for a service.

The process was designed to be generic so that it can be used for more general applications. The governance reference model was developed and then documented with UML diagrams.

In Phase III the governance reference model was implemented on a PC-based Windows platform in the design-time and run-time environment provided by Web Services Oxygenated (WSO2). A prototype was created based on the design strategies and revised governance reference model developed in Phase II. A data service was created using the prototype to demonstrate Quality of Service (QoS) that validated the governance reference model.

An evaluation of the implemented governance reference model and prototype was conducted in Phase IV to ensure the original objectives of the research had been achieved. First, the prototype was verified against its original requirements. Second, the implementation of each design strategy was analyzed to ensure each had a direct effect on the implemented governance reference model and prototype. Third, the governance reference model was validated by comparing the results achieved with the prototype against the original tenets of the dissertation. Specifically, it was shown that the governance reference model for SOA-based data initialization of military simulation and C2 systems:

- provides a common reference to promote reusable data services that initialize common data products from various authoritative data sources,

- supports reusable policies, standards, and processes across varying simulations and inter-service domains,
- provides greater common data consistency, verification, validation, and re-use,
- allows sharing of common data assets,
- provides easier common data migration & change management, and
- provides improved definition of policies and agreements for common data assets across the SOA environment.

It should be noted that the governance reference model and governance-oriented SOA was designed for generalization, but tested only for initialization as presented in the military simulation case study. The scope of this research was limited to common data initialization issues in military simulation. This research does not include testing, evaluation, verification, validation, or recommendations for systems or models in domains outside of common data initialization for military simulation. Further research is required in order to fully “generalize” and apply the findings of this research in other domains.

#### **5.4 Original Contributions**

A number of original contributions have been made by the research. This research represents the design and implementation of a new governance reference model for SOA-based data initialization of military simulation and C2 systems. It is based on a new consolidated analysis of the priorities, goals, and best practices of military and industry stakeholders. A new set of solutions and design strategies have been created and tested to

meet these priorities and goals. Furthermore this research presents and documents the following products:

- Structured Interview Data: (Appendix A)
  - Interviews were conducted with Subject Matter Experts (SMEs) in the fields of service oriented architecture, governance, business models, and data initialization. The SME input was collected using structured questionnaires and synthesized to identify factors and impacts.
- Factors and Impacts:
  - A synthesis of the structured interviews produced a list of factors and impacts (Appendix B) that the SMEs perceived to be critical to the design consideration of the revised governance reference model. Factors are grouped into a set of related fundamental issues.
- Issues – Solutions and Strategies:
  - For each fundamental issue identified, a general modeling solution was identified that would be used to resolve the issue or mitigate its impact. For each solution, one or more specific design strategies were developed that would help define the structure of the revised governance reference model (Appendix C).
- Revised Governance Reference Model:
  - The revised governance reference model is derived from interviews with SMEs and corresponding factors, issues, solutions and strategies, and documented using UML (Appendix D).

- Governance Reference Model Developmental Process: Stages and Threads:
  - The governance model developmental process is derived from SME insights and strategies, and organizational best practices. The process is used to drive the creation of a high-level architectural design that incorporates revisions to existing SOA design and moves it all into what is referred to below as Governance-oriented SOA (G-SOA). Also, the process provides opportunity for improvement by iterating enhancements back into the governance reference model and process.
- Governance-oriented Service Oriented Architecture (G-SOA):
  - As a revision to the traditional Service-oriented Architecture, a Governance-oriented SOA is proposed. The G-SOA design is implemented using the easily understood Business Process Modeling (BPM) notation (section 4.3.2). Further a prototype is implemented that conforms to G-SOA (Appendix E).
- Prototype:
  - The prototype is a Governance-oriented SOA-based application implemented using web-services technology (section 4.3.3). The implementation is driven by the G-SOA described above.
- Data and Analysis:
  - The revised governance reference model, proposed G-SOA, and prototype are evaluated based on requirements identified by expert input, expert evaluation, and published organizational best practices (section 4.4).

Finally, industry and government sectors implementing SOAs have found that governance is one of the most important topics associated with achieving a successful Network-Centric Environment. As described in Chapter 1, lack of governance was identified to be the largest factor inhibiting SOA adoption (InfoWorld, 2006). As such, there is motivation to implement products that guide the development of a governance-oriented SOA environment. This dissertation focuses service development on the common data initialization SOA-based military simulation and command and control systems. However, all products described above can be generalized and made capable of supporting SOA-based systems of many types and flexible enough to support incorporation of new SOA-based information technology and simulation-related technologies.

### **5.5 Solution to a Previous Weakness**

A governance reference model in developing SOA-based data initialization services for joint military federation simulation and C2 systems would address many of the weaknesses to previous SOA-based strategies. The G-SOA:

- has the potential to allow full interoperability of common initialization data and tools across a federation (Tolk, 2003; Shane, 2005)
- may reduce costs because of the savings gained from faster initialization of common data and interoperability, and reusable services and tools (Blalock, 2005; Tolk, 2007)
- could be used as a reference model across many other organizations and their respective SOA-based simulation systems (Tolk, 2003; ZapThink, 2006)

- will allow SOA-based solutions to further satisfy the DoD requirement for systems to meet the Net-centric Enterprise Service objective (Vietmeyer, 2005; DoD-CIO, 2006)

SOA governance identified in open references is primarily proprietary. Examples include:

- IBM (proprietary)
  - SOA Governance Lifecycle
- Oracle (proprietary)
  - Six Steps to Successful Governance with SOA
- Microsoft Corporation (proprietary)
  - Governance for SOA Systems

However, there are published (non-proprietary) governance solutions available. Examples include:

- OASIS (non-proprietary)
  - Reference Architecture Foundation for SOA
- OpenGroup (non-proprietary)
  - Guide to SOA Governance

Gaps were identified in current SOA governance solutions that were addressed in this research. The OASIS Reference Architecture Foundation for SOA (figure 32) is an example where best practices, concept extensions, and gaps in governance were identified and addressed in the *revised* governance reference model.



OASIS is a non-profit consortium that drives development, convergence, and adoption of open standards in information technology. Figure 32 illustrates the OASIS Reference Architecture Foundation for SOA. Governance exists as an entity with the reference architecture and is extended in figure 33.

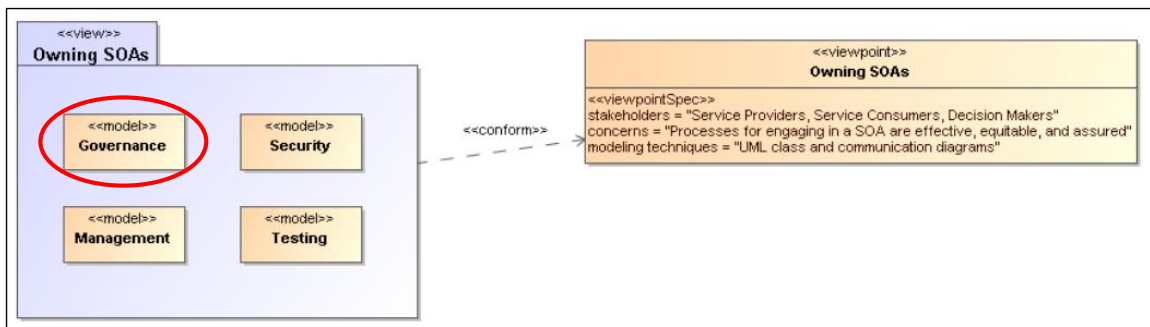


Figure 32: OASIS Reference Architecture Foundation for SOA

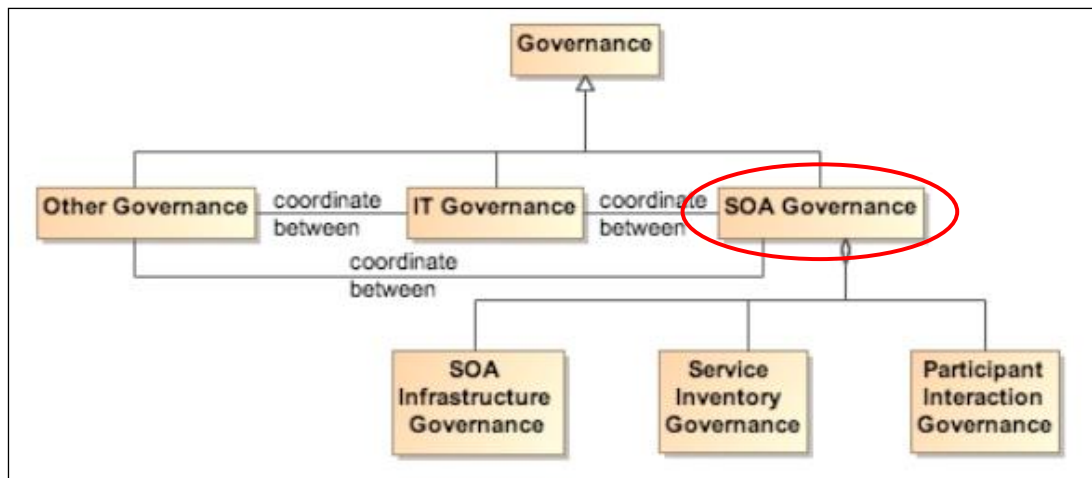


Figure 33: OASIS Governance Reference Model

Figure 33 illustrates the OASIS Governance Reference Model that includes the SOA Governance Reference Model and its respective elements: SOA Infrastructure

Governance, Service Inventory Governance, and Participant Interaction Governance. Best practices were extracted from the three elements and mapped to the three stages of the *revised* governance reference model.

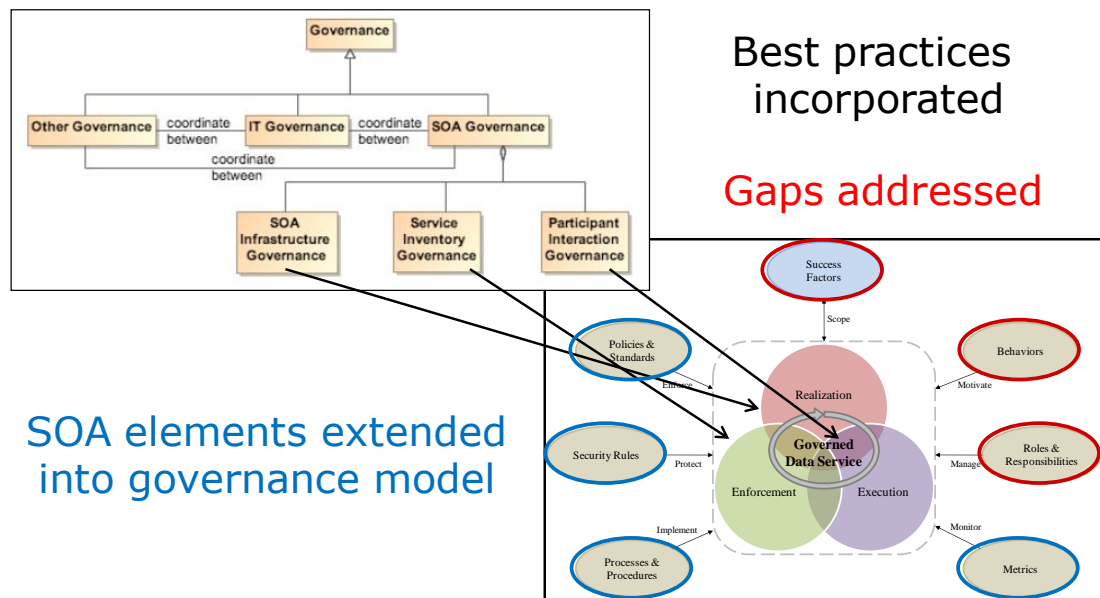


Figure 34: SOA Governance Model Comparison

Furthermore, figure 34 illustrates the extension of SOA elements from the OASIS Governance Reference Model into the *revised* governance reference model annotated by the blue ovals highlighting the threads for Policies & Standards, Security Rules, Processes & Procedures, and Metrics. Lastly, figure 34 shows the gaps identified in the OASIS Governance Reference Model, and addressed in the *revised* governance reference model annotated by the red ovals highlighting the threads for Success Factors, Behaviors, and Roles & Responsibilities.

## 5.6 Limitations of Research and Obstacles to Overcome

While the governance reference model has demonstrated that it is capable of meeting the objectives of this research, a number of topics have been identified that the governance reference model does not explicitly address, and a number of limitations are known that constrain this implementation. These topics have been identified both by the author and by other SOA, governance, business model, and data initialization experts that have reviewed the design documentation, and they are briefly discussed here:

- *Proof of concept only:* While governance reference model design decisions were made based on input from experienced subject matter experts, no attempt has been made to test the prototype in its respective domain. Until the governance reference model has proven itself in the field it remains a proof of concept.
- *Immaturity of the reference models and corresponding entities:* A minimalist approach was taken in designing the reference model and entities with the intention of developing only what was absolutely required for the governance reference model to execute. Specifically a significant amount of work is needed on the success factors and behaviors models and corresponding entities to support full scope compliance and motivation.
- *Governance reference model evolution:* Gartner (2008) states that a governance reference model must not only be defined but maintained to suit the evolution of its entities. At this time no methodology has been identified to

support the evolution and maturation of the governance reference model or its adaptation to different projects and development processes.

- *Tools*: While considerable thought was given to how the governance reference model would support various data service development tools, no attempt was made to develop formal tools that would aid in developing and integrating reference model entities or building a military simulation and C2 federation. Examples of such tools could include an automated data service validation tool, an encryption and interface negotiation tool, and a scenario generation tool.
- *Scalability*: Further work is necessary
  - Before large-scale implementation
    - Further decompose *revised* governance reference model
    - Identify potential data collection tools
    - Test scalability and performance for greater number of services and larger data sets
  - During large-scale implementation
    - Monitor and evaluate implementation metrics
  - After the large-scale implementation
    - Analyze collected metrics for areas of improvement
    - Conduct and analyze user evaluation data

## **5.7 Future Research Opportunities**

Assuming that the obstacles listed in the previous section can be addressed; there are several areas of interest where future research opportunities may exist:

- Governance Reference Model process improvement methodology
- Automated verification and validation techniques
- Autonomous agents
- Semantic web services
- Virtualization

The development of a governance reference model process improvement methodology will be essential for maturity advancement. There must be a mechanism set in place to drive the iterative improvement of the governance reference model and associated processes such that the model may mature with the organization over time. There are several published SOA maturity models (IBM, 2008) in literature that may be leveraged or extended to inherently drive process improvement.

As the number of data services and data sources increase so does the need for automated verification and validation techniques. Future research should investigate tools and processes for automating the verification and validation of newly developed, modified, and replicated data services. Furthermore, as more data sources are linked to data services for extracting, formulating, and formatting data, there is a greater risk for data inconsistency. Automated verification and validation techniques (or perhaps services) may provide solutions to ensuring consistent data propagation.

It would be beneficial to further research the use of autonomous agents as services for mining specific data elements from various authoritative data silos. In addition, data service agents may be used to syntactically and semantically build common data sets for initializing federations. Autonomous agents may be useful by providing intelligence in collecting behaviors and patterns for determining incentives and penalties as well.

The mainstream XML standards for interoperation of web services specify only syntactic interoperability, not the semantic meaning of messages. For example, the Web Services Description Language (WSDL) can specify the operations available through a web service and the structure of data sent and received but cannot specify semantic meaning of the data or semantic constraints on the data. This requires programmers to reach specific agreements on the interaction of web services and makes automatic web service composition difficult. Semantic web services are built around universal standards for the interchange of semantic data (Zeng, 2001), which makes it easy for programmers to combine data from different sources and services without losing meaning. Web services can be activated ‘behind the scenes’ when a web browser makes a request to a web server, which then uses various web services to construct a more sophisticated reply than it would have been able to do on its own. Semantic web services can also be used by automatic programs that run without any connection to a web browser (Zeng, 2001).

Finally, with the recent prevalence of integrated online solutions, it would be beneficial to research the possibility of implementing a full virtualized implementation of the governance reference model. SOA-based data initialization has the potential to allow disparate data elements of a single federation to be hosted on separate servers in different

parts of the world while clients would be presented with a seamless virtual environment. It would be worthwhile to test out this distributed SOA-based data initialization concept as it has the potential to alleviate many of the problems associated with data access, data redundancy, and data inconsistency.

## **APPENDIX A: STRUCTURED INTERVIEWS**



**Question 1: SOA:** *In the attached journal article, Service-oriented Architecture (SOA) is defined by OASIS as: “A paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains...” Dr. Thomas Erl defines SOA as: “An architectural model that aims to enhance the efficiency, agility and productivity of an enterprise by positioning services as the primary means through which solution logic is represented in support of the realization of strategic goals associated with Service Oriented Computing”. Lastly, J. Dorn defines SOA as: “A shift in the information system paradigm from document-centric transactions of business information to process-centric and service-based data exchange.” Which definition is closest to your own definition? If you feel that the current best definition is still inadequate, what would you rewrite in the current best SOA definition?*

**Answer 1:** Industry Definition of Service-Oriented Architecture (Source- Web Services and Services Oriented Architectures, by Douglas K. Barry, 2003):

- A service is a function that is well-defined, self-contained, and does not depend on the context or state of other services.
- A service-oriented architecture is a collection of services. These services communicate with each other, e.g., simple data passing or two or more services coordinating an activity.
- SOA characteristics and principles:
  - Loose Coupling
  - Location Transparency
  - Protocol Independence

Another design concept of SOA is that the data is separated from the application services. My favorite quote about SOA (source- Gartner Inc.): “SOA does not solve your data problems- it exposes them!”. The DoD Net-Centric Data Strategy addresses the need for data to be visible, accessible, understandable, trustworthy, interoperable, and responsive.

**Answer 2:** I agree with SOA definition from OASIS because they are an open-source community with members of various disciplines and perspectives. However, I would include that SOA is an attempt to provide a set of principles or governing concepts that are used during the phases of systems development and integration.

**Answer 3:** All definitions described are acceptable. SOA is a very broad and overloaded term. Typically SOA consists of a collection of applications that provide (computational) services via a well-defined API where services are self-contained and asynchronous.

**Answer 4:** SOA governance provides the policies that may be checked automatically or via human intervention in supporting how services are defined, developed, configured, accredited, deployed, and used.

**Answer 5:** The definition by Thomas Erl because he is an authority in the subject of SOA.

**Answer 6:** OASIS definition reflects much of what SOA entails.

**Answer 7:** SOA definition (source- Organization for the Advancement of Structured Information Standards (OASIS)):

- A paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains. It provides a uniform means to offer,

discover, interact with and use capabilities to produce desired effects consistent with measurable preconditions and expectations.

- SOA is not about any particular technology. Instead, it can be looked upon as a design philosophy that separates the following:

**Core Functions:** Functions that are called by one or more presentation applications. These functions are stable and common; and are encapsulated by services within SOA.

**Operational Processes:** Rules and methods of operation that can change and grow at a fast pace. As data domains evolve they can add more and more steps and possible alternates or decisions to their operational processes. The services being used by these operational processes do not change much; however, the pathways through the operational processes do.

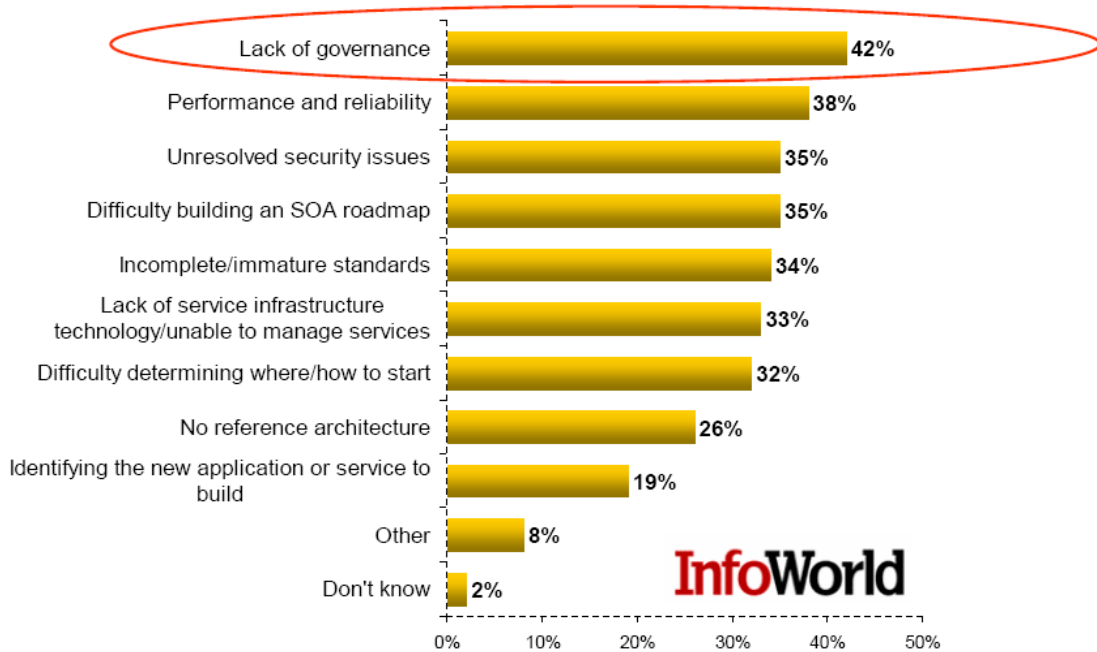
**Presentation Applications:** Volatile software that presents data to and accepts data from various users. These applications may present the data in various ways according to user preference and requirements (i.e., display descriptive data, display a data summary, make use of different colors, font-faces, and layouts).

**Answer 8:** A SOA provides (given the appropriate metadata) data visibility and accessibility. Also, with the appropriate data standards and standard information exchange data models, data mediation services can provide data interoperability.

**Answer 9:** SOA is essentially a collection of services. These services communicate with each other, which involves either simple data passing or two or more services coordinating some activity. SOA is not new, it has been around for years. Although significant challenges still remain, the recent evolution of both open-standards based

technology and implementation processes have enabled radical improvements in SOA capabilities.

**Question 2: SOA:** *An InfoWorld study released in July 2006 (figure below) determined that 42% of the SOA projects examined identified a lack of governance to be the largest factor inhibiting SOA adoption. Governance factors cited as being the most lacking that inhibited SOA adoption were: (1) Implementation of service processes and procedures, (2) Enforcement of service policies and standards, (3) Monitoring and evaluation of services using metrics, (4) Management of service and user roles and responsibilities, and (5) Incentivizing user behaviors. Is the list below of factors that inhibit SOA complete? If not, what is missing? Are any of these SOA inhibiting factors inhibiting your organization from either adopting or advancing SOA within your organization? To the extent of your knowledge please list in chronological order the SOA inhibiting factors that your organization has overcome. Can you estimate how long it took to overcome each SOA inhibiting factor in order to establish a baseline SOA? What SOA inhibiting factors is your organization currently working on? What SOA inhibiting factors does your organization plan to address or overcome during the next year in order to raise the SOA level in your organization?*



**Answer 1:** Most of my experience concerns the technical design and implementation of prototype SOAs and the related metadata, data standards, standard information exchange data models, and domain ontology. However, I do understand the importance of DoD governance of SOA (GIG) design, implementation, and maintenance of the SOA.

The shift from client applications/server architecture (with engineered point-to-point interfaces) to a SOA with services/data made available to many users (anticipated and unanticipated users with the proper permissions) is a major paradigm shift for the DoD. It is technically difficult and expensive to convert legacy architectures to a SOA. The DoD Net Centric Data Strategy calls for the establishment of COIs to establish domain-specific data standards, standard information exchange data models, and ontology. There are a vast number of domains and sub-domains across the Joint and service-specific warfighter and business oriented domains of the DoD. Currently there are a relatively

small number of COIs that are actively establishing domain data models/ontologies and WSDL/XSD for domain-specific web services. There are DoD COI registries and DoD metadata registries to post/reuse domain data models, ontologies, WSDL, XSD, etc., however, many times there are overlaps or linkages between COIs and there is very little governance oversight to ensure that the proper coordination is conducted between COIs. In my experience, within the Army C4I domain and the Army training M&S domain, it is programmatically difficult for these two communities to share common data or establish common data standards and information exchange data models. The Army C4I architectures have evolved in isolation of the Army LVC M&S architectures. Neither architecture currently uses a SOA, however, the DCGS-A is the first web service C4I system to interface with an Army constructive M&S federation (JLCCTC). Army C4I program managers (PMs) have no official requirements (and thus no resources) to integrate architectures or share common data with Army LVC M&S architectures. The only integration of architectures between these two communities has been the exchange of standard tactical C2 messages through SIM-C2 interface translation boxes (“C2 adapters”) to stimulate C2 systems during a training exercise or test event. Only the Future Combat System (FCS) program has official requirements to integrate the C4I and M&S architecture. The SIMCI OIPT coordinates solutions to SIM-C4I interoperability technical issues between the two communities; however, the OIPT is not a governance body. The Army CIO/G6 has only started to put the governance structure in place for the establishment of web services across all domains, establishment of data standards, and the configuration management of Army-specific extensions to domain-specific standard

information exchange data models such as the JC3IEDM for the Army C4I and M&S domains (see attached Army CIO/G6 files).

**Answer 2:** Factors include: Insufficient documentation of interfaces, insufficient semantic transparency of services, solutions limited to the technical level, insufficient conceptual work, experts don't have the needed education (we need SOA architects, not only systems/software engineers), unwillingness to support the necessary semantic transparency, and too many conceptual misalignments between the legacy solutions.

**Answer 3:** Defense contracting has many rules and regulations. Profit margin is very slim for defense contractors. The different motivations that exist between Government and industry: For example, industry likes to sell products and sometimes rent services but likes to retain IP and get continuing revenue stream whenever possible. Whereas, government wants visibility for information assurance reasons and wants low cost solutions that work consistently and realistically.

**Answer 4:** Receiving authority and support to implement and enforce policies and governance focused at the federation or enterprise level vice the independent federate level. The lack of specified governance policies and insufficient early lifecycle enforcement of policies. The risk is that independent service developers will make assumptions about specifications and policies and if sufficient early checks are not made the services will not align to perform necessary end user capabilities and will require more technicians to bridge the gap.

**Answer 5:** Governance has always been an issue with respect to SOA because there is little guidance as to how to implement it into a SOA environment or system. There are



many proprietary models from various commercial organizations, but they typically do not include best practices. In my organization, I would say that the following SOA governance activities should be considered: Security, Roles & Responsibilities, Standards, Policies, Enforcement and Compliance, and Metrics for quantifying quality and performance.

**Answer 6:** The decision to implement SOA in an organization requires an extraordinary commitment from senior leadership. Senior leaders must articulate the vision for the effectiveness desired from a web-based approach to information sharing as well as the value of moving beyond simple process automation to the ability to rigorously answer key business questions in real time. More importantly, leaders must anticipate and aggressively attack cultural resistance to the availability and sharing of information throughout their enterprise, and promote the value that consolidation and self-service enablement brings. This requires clear, consistent evangelizing and messaging.

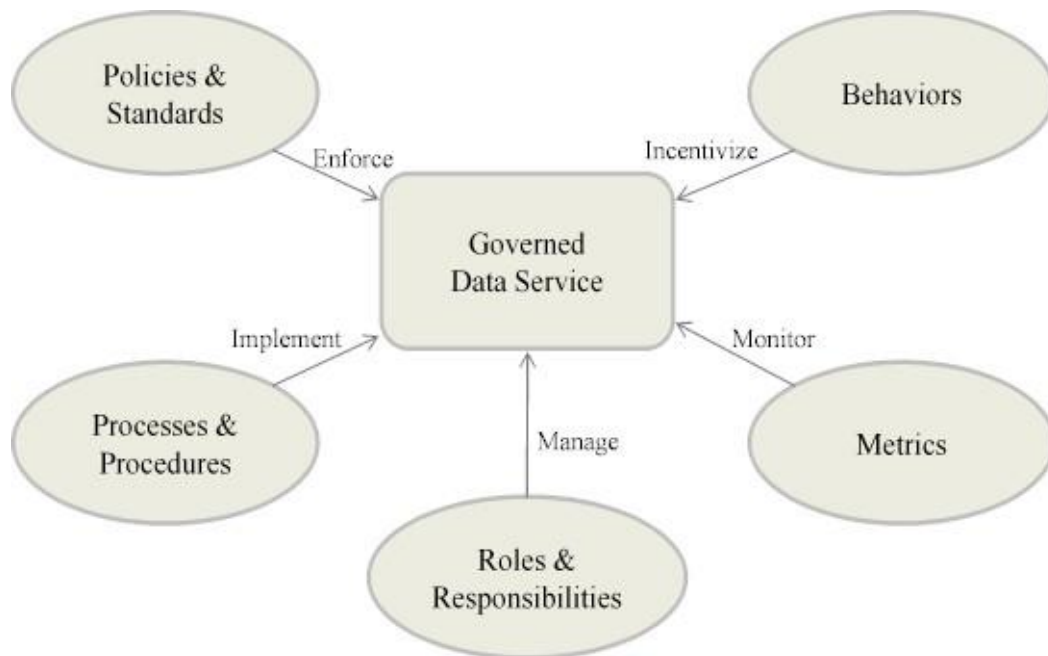
**Answer 7:** To ensure SOA success, you should enact policies and supporting processes that support the delivery of the SOA Roadmap. You should communicate them widely, and then monitor their implementation and make adjustments as you go. This is the essence of governance with SOA—enacting policies and procedures to ensure the timely and appropriate execution of your SOA Roadmap.

**Answer 8:** SOA governance should extend the organization's existing IT and EA governance models to cater for the new SOA assets and SOA policies. Extending these existing governance models reduces the risk that organizations will create uncoordinated silo'ed governance regimens that will potentially duplicate existing coverage areas of

their core governance regimens. Extending the existing governance regimen to ensure that the benefits of SOA are achieved is still challenging. It requires governing the strategic planning activities as well as the execution aspects of SOA.

**Answer 9:** To meet business and SOA goals, policies must be enacted across the different business areas: architecture, technology infrastructure, information, finance, portfolios, people, projects (or rather, the way in which projects are executed) and operations. This is the role of governance: i.e. policies, which need to be designed and enacted to ensure this alignment. The format and medium for policies may be different - some policies can be captured and enforced in technology, for example, a registry/repository aids in enforcing service lifecycle governance, and a web-services management solution realizes the application of operational policies to services at runtime. Other policies, such as architectural policies, or funding policies need to be captured through policy documents that are distributed through the organization.

**Question 3: Governance:** *Mr. M. Josuttis stated in his textbook, **SOA In Practice: The Art of Distributed System Design**: “The goal of SOA governance is to develop processes and oversight to ensure that services are developed and sustained to promote a flexible and dynamic infrastructure.” Further, an initial GOVERNANCE reference model as shown in the figure below has been proposed in the attached journal article<sup>1</sup>. In your mind, does the figure below reflect all the key concerns that impact successful SOA Governance? What other activities and relationships (if any) should be included in the Initial Governance Reference Model? What activities and relationships should be removed or modified? Can you identify and describe any gaps in the Initial Governance Reference Model? For example, would you define Security within the context of the Initial Governance Reference Model below or prefer to propose a different Governance Reference Model?*



**Answer 1:** Governance involves the programmatic oversight of DoD (DISA) and service (USA, USN, USAF, USMC) efforts to establish and sustain the GIG (LandWarNet, FORCEnet, and Constellation Net) SOA and the implementation of the DoD Net Centric Data Strategy. This governance includes the establishment and integration of core Net Centric Enterprise Services (NCES) along with Joint and service-specific services including domain (COI)-specific services and cross-domain (COI) services. Although there are many commercial standards to implement a SOA (UDDI, WSDL, XML, XSD, XSLT, SOAP, RDF, OWL, etc.), close coordination of the technical details of web service implementation is required to ensure interoperability between services, service/data providers, and service/data consumers. Consider areas in Quality of Service (QoS), Service Composability, Extensibility, Federation, layers of abstraction, and organizational agility.

**Answer 2:** Policies for specific W3C recommended solutions (ie SOAP, XML, WSDL for service description and implementation, and ISO/IEC 11179 for metadata).

**Answer 3:** Suggest including Security as a component of the proposed reference model. However, also suggest decomposing Security to include specific components for: Authentication, Authorization, Trust, Integrity, Identity, etc. Also, may want to relate Security to its associated processes and policies.

**Answer 4:** I would recommend types of services associated with information assurance, data quality and authority, and intended use of data.

**Answer 5:** Policies facilitate the development of ontologies, naming guidelines and services, data standards, and taxonomies. These policies also set the framework for establishing authoritative data sources.

**Answer 6:** A proactive establishment of control and incentive mechanisms requires strong top-down policy and governance. Further, a top-down approach facilitates security across organizational boundaries. However, user and system owner engagement—through bottom-up leadership—is critical. Both approaches offer important advantages. An enterprise implementing SOA needs a proactive top-down policy that facilitates a cross-organizational approach, as most likely the environment is not under the control of a single organization or project. For example, Wells Fargo conducted an audit of the 15 internal IT services providers that support the bank (which is the fifth largest in the U.S.) and found over 700 web services in use, with many more in development. Wells Fargo managed this proliferation of services with a centralized mechanism for web service registration, discovery, and re-use.

**Answer 7:** Architectural policies provide the foundation and framework for your SOA and enable you to build it better, faster, and cheaper. Every system must be built so that it both fits into your existing environment and reflects your organization's future vision and SOA strategy. Building out your SOA to enable change is best done using an architectural approach that sets up a minimal set of constraints, thereby realizing consistency in service implementation, improved interoperability, stakeholder innovation, and enablement of applications that are minimally developed, yet offer general-purpose capabilities that are useful to other applications and take advantage of and enhance a

shared infrastructure. As part of your SOA journey, you should consider policies built around:

- Standards compliance—for example, WS-I Basic Profile compliance for service interfaces
- Use of architectural assessments, including reviews and change processes
- Utilization of architecture documents and guidelines covering use cases, views, service interface design, and design patterns
- Use of service-based application blueprints
- Adherence to reference architectures

**Answer 8:** The SOA governance program should support the business and IT drivers. Business and IT stakeholders must participate in governing and enforcing the organization's SOA program. Contracts should exist between service providers and consumers. Contracts may be dictated by one party. Stakeholders shall be identified and accept responsibility for the governance process(es). Service contracts adherence should be monitored. Metrics should be gathered and available. Service design and run-time policies should be enforced.

**Answer 9:** Governing Processes realize the governance intentions of the organization. These are the processes that a governance model uses to govern any particular process. Governed processes are the actual processes being controlled, monitored, and measured (e.g., testing, design, and deployment). Model should include compliance, dispensation, and communication.

- Compliance: The purpose of this activity is to define a method to ensure that the SOA policies, guidelines, and standards are adhered to. The Compliance process provides the mechanism for review and approval or rejection against the criteria established in the governance framework (i.e., principles, standards, roles, and responsibilities, etc.). In many cases, it is an add-on to the existing quality review process.
- Dispensation: The Dispensation process is the exception and appeals process that allows a project or application team to appeal non-compliance to established processes, standards, policies, and guidelines as defined within the governance regimen. Examples include service funding, service ownership, service identification, etc. The result would be a granted exception.
- Communication: Communication processes educate, communicate, and support the SOA Governance Regimen and SOA policies, guidelines, and standards across the organization. This also includes ensuring that the governing processes are acknowledged within the governed processes. Communication processes should ensure that the governance is understood. It should also ensure access to and use of governance information.

**Question 4: SOA and SOA Governance:** *Eric Marks and Michael Bell note in their book, **Service Oriented Architecture: A Planning and Implementation Guide for Business and Technology**, that there is a paradigm shift in an organizations' business model in order to implement SOA and SOA governance. With this shift, there is a significant learning curve that directly affects initial and long term cost and schedule. Literature points out that the initial cost and schedule are high but reduce significantly as the organizational SOA enterprise matures. What do you perceive to be the most challenging business related obstacles to implementing, operating, or using an effective SOA governance reference model for your organization?*

**Answer 1:** I agree that costs and time are becoming more difficult to justify to government and military leadership. Especially since serious games can produce very similar training results with much less footprint. This issue is mainly political and not so much technical. Though, a lack of governance precedence is another reason of high costs and schedule slips. Not many have actually tried to model and/or document this behavior. Certainly having a foundation like a reference model to start would at the very least initiate discussions on future policies. Providing this mechanism, especially in a central registry with automated checks, would be very useful in reduction of costs and schedule.

**Answer 2:** Advantages is that SOA can be easy to implement. However, a disadvantage: is that you can glue things technically together that don't match conceptually.



**Answer 3:** The major challenge is interoperability between data elements due to that there are many non-common model formulations for simulations, and non-common communication protocols for C2.

**Answer 4:** Governance processes must be similarly adaptive and flexible; what the enterprise needs, what systems the enterprise will build, and how those systems will be built will be much different tomorrow than they are today. Of course, the enterprise must also stay within fiscal constraints. Our organization must have discipline and rigor in the enforcement of the architectures, standards, and policies we adopt for SOA because without rigorous governance, we will not realize SOA's potential benefits.

Gartner cautions, "Service-oriented architecture built opportunistically with the purpose of "getting it over with" as soon as possible, and at as low a cost as possible, will prove to be a disaster for enterprises' software infrastructures." Accordingly, simplicity, interoperability based on open standards, scalability, and loosely coupled, modular services are keys to an effective governance process in our organization's dynamic environment.

**Answer 5:** To gain the most reusability across lines of business, departments, and projects, it is important to create standards to which architects can design solutions. This is typically accomplished through reference architectures that are used as both blueprints for new designs and a yardstick by which architectures should be evaluated. Many organizations face "siloed" business models in which there are no shared designs, policies, or processes across the business lines. These organizations often work harder to create seamless integration with business partners than they do within their own internal

divisions. But the architecture discipline must be aligned within companies or they will not be able to gain the maximum benefits of SOA, such as service reuse and reduced maintenance costs. Oracle recommends that companies create a single, consolidated reference architecture implemented across the entire enterprise. By keeping your enterprise architecture artifacts simple, you increase the chances that your audience will understand them, project teams will actually read them, and you will be able to effectively enforce and update them over time. An enterprise may create separate architectures for: applications, integration, security, and data, or a single reference architecture that encompasses all of these domains. This solution architecture is sometimes referred to as a composition-architecture. What is important is that the enterprise architecture group defines a common blueprint for new application development and integration, with standard interfaces for easier assembly and maintenance.

**Answer 6:** Existing services should always be considered first when creating new SOA solutions. Re-use before buy before build to decrease cost and complexity. Also, ensuring proper cost allocation for service development and execution can be a challenge, but should be considered.

**Answer 7:** Leadership is key, as ongoing operations demonstrate the worth of web services and SOA—increased organizational effectiveness with radically improved access to information and collaboration, reduced costs with reusable assets, reduced personnel requirements, and improved customer satisfaction and employee morale.

**Answer 8:** An enterprise should implement “low-hanging fruit,” followed by the execution of back-end migrations, and then migrate applications to services interfaces. The enterprise should give priority to the incremental change that has the clearest, strongest business value, while recalling that some changes are high-impact because they enable other changes. Many organizations emphasize the importance of a registry for web services and recommend the following steps for web services implementation: 1) Implement a single (logical) registry. 2) Incorporate portfolio management and lifecycle management for services as part of the governance model. 3) Have a central team manage the registry. Here are two examples of organizations implementing SOA in simple, accessible circumstances: One IT firm implemented a content creation and web publishing system thereby automating a formerly manual process resulting in savings of \$180,000 a month and reduced submission time from four hours to 15 minutes. The Ministry of Revenue Quebec grew its on-line tax remittance model step by step. The current version is fairly well evolved and has generated significant time and cost savings.

**Answer 9:** The challenge is that policies must be enacted to create and use an enterprise layer that logically centralizes access to the data spread across the enterprise. This set of logically centralized data services provides several architectural advantages. First, the enterprise can assert greater control over the governance and implementation of data access mechanisms. Second, clients use a consistent mechanism to access data. Third, the enterprise can design and implement a solution in a holistic fashion instead of the typical one-off models that are the norm in data integration, thereby reducing cost and improving information quality. Finally, besides the basic Create, Read, Update, and Delete (CRUD)

operations, the underlying architecture can support data aggregation, inter-service transactions, and multiple access and usage patterns, all while ensuring acceptable levels of quality of service.

**Question 5: Business Model:** *The attached article<sup>1</sup> describes related work in SOA governance and data exchange within government (i.e. MSDL standard, BML standard, Objective Initialization Capability), industry (i.e. IBM, Oracle, HP, ZapThink, etc.), and academic (i.e. JEDIS) organizations. However, due to variants within organizations, there is no single business model that promotes well-defined SOA governance. Examples of these invariants include the existing governance in place, the SOA maturity level (if applicable), size of the organization, etc. How would you begin to develop a business model that incorporates SOA and SOA governance for data exchange? Based on your ideal business model:*

- a. What decisions need to be made in an organization to have effective SOA governance?*
- b. Who should make these SOA governance decisions in an organization?*
- c. How will these SOA governance decisions be made and monitored in an organization?*
- d. What organization structures, processes, and tools should be deployed in an organization?*
- e. What metrics are required to ensure that an organization's SOA implementation meets their strategic goals?*

**Answer 1:** (a) Certainly the roles and responsibilities must be established in order to properly manage SOA governance and services that are developed. (b) Decisions should be made by the stakeholders involved in the SOA environment. (c) Decisions should be made through processes and monitored by a control group or governance body. (d) A SOA enterprise service bus and security mechanism that protects the SOA infrastructure and data should be deployed. (e) Quality of Service (QoS) metrics.

**Answer 2:** For the technological transformation (tactical dimension) to succeed, the strategic focus needs to address the business, organization, people, processes and culture. Further, the focus needs to address how these resources are defined and used in the business model. Leadership must recognize that the technical issues are not the hard part; the real challenge is the socialization of the service vice system approach and the business case for delivering the services. The IT support organizations or vendors, in particular, must be focused around business services and processes. The business model should analyze the results of the governance policies that are in place and gather metrics on the governance processes themselves, including their effectiveness. Also, the business model should measure the progress that you have made on your SOA Roadmap, relaxing overly restrictive policies where it makes sense and taking corrective action where necessary. A lot of companies separate “policies” (have to follow) from “guidelines” (should follow). Remember, you want to have an open environment in which people communicate their actions and experiences when they go off the beaten path.

**Answer 3:** SOA managers must use decisions, processes, and policies to encourage the behavior that contributes to success. In the case of SOA adoption, SOA governance can be defined as the interaction between policies (what), decision-makers (who), and processes (how) in order to ensure SOA success. Metrics will show what aspects of governance are working and what aspects require change.

**Answer 4:** As governance events take place, various metrics should be gathered that provide information on the quality of the tasks that SOA governance is governing. Management and measurements of goals help an organization to judge the effectiveness

of the SOA governance effort and where additional discipline is needed. SOA governance like any other discipline needs to first define a set of goals that it strives to achieve. A corresponding set of metrics should be defined to measure the goals that the governance framework strives to achieve. SOA governance is responsible for periodically reviewing these metrics and making the needed changes to governance policies, standards, and processes through iterations of the governance model lifecycle. The monitoring of metrics of the governed processes, service portfolio and lifecycle management as well as solution portfolio and lifecycle management, happens constantly. Evaluation may happen in real-time or periodically; i.e., weekly, monthly, quarterly, or yearly. Some real-time monitoring metrics could be provided by SOA business activity monitoring tools.

**Answer 5:** Leaders must identify business and IT imperatives, along with the targeted business outcomes and SOA metrics, during the early phase of the SOA strategy and planning process.

**Answer 6:** When an organization supports a business model that cuts across organization lines, vertically and horizontally, and when an organization provides for the orchestration of services in support of essential business functions, the organization maximizes the flexibility of SOA. In fact, optimizing resources across organizations and systems enhances collaboration and leverages existing IT investments. At the same time, one must recognize the inherent differences and diversity in operational contexts across domain and enterprise boundaries and develop solutions that accept and deal with these essential differences so that all stakeholders in the enterprise get the support they need.

**Answer 7:** A and B: The leadership must make decisions about the general standards model(s) that will be implemented across the enterprise and within communities of interest. C: Through a proper process via a governance body and stakeholders. D: The realization of net-centricity continues to evolve as more and more organizational entities, users, processes, functional capabilities, and data become interconnected. Net-centricity gains its power through the ability to leverage and re-use data, services, and processes across functions, domains, and organizations. Efficiency, without loss of effectiveness, in the establishment, modification, and use of data, emerges within this concept. Interdependent operations can also be accomplished faster and with greater efficiency, and, in general, greater effectiveness. Finally, the distribution and tempo of decisions and resulting actions across functions can increase. E: Quality metrics such as: performance, availability, and reliability.

**Answer 8:** Provide industry input on best commercial practices, service environment business models, internal industry practices, and applicability of those practices and models to the DoD. By applying metrics, organizations may notice that the percentage of rejections for service design is trending upward and it is necessary to find out why and take action. An investigation in this case may show that a particular policy is causing this rejection. The governance team would then need to consider whether the policy is too restrictive or if further education needs to take place. In any case, such periodic reviews will identify areas of concern and follow-up action.

**Answer 9:** SOA guidelines development includes the articulation of, and update of policies, principles, standards, and guidelines. This process needs to be monitored and



governed just like the other SOA processes. Performance metrics should be established that can be monitored and evaluated periodically: daily, weekly, monthly, quarterly, or yearly. Sufficient changes to these guidelines may cause an iteration of the governance model lifecycle to bring the governance regimen into alignment with the new guidelines. Provide a mechanism to evaluate initiatives and/or projects with regard to the organization's desired degree of SOA focus based on overall SOA strategy and current maturity level. The portfolio management process may need to be updated to ensure the right mix of projects is selected that advance the ability of the business to be agile. This includes an assessment of services from a project to determine the value of those services beyond that of the project itself. SOA governance needs to ensure that the benefits of service re-use for a particular project are reflected in project selection and prioritization.

**Question 6:** *What additional advice and recommendations do you have for someone developing a SOA governance reference model for military simulation and C2 federation needs?*

**Answer 1:** The evolution of the Army C4I “system of systems” and the M&S federation is similar because originally individual C2 systems and individual simulations were developed to operate “stand alone” within their own battlefield functional area (maneuver, fire support, intel, logistics, etc.). Each C2 system and simulation was designed to manually generate its own initialization data, without any common data standards, and in its own native format and schema (relational database, text files, XML files, etc.). Then C2 systems were “federated” together with data exchange through standard tactical C2 message formats (VMF, USMTF, and others). Later, direct DB-to-DB data exchange was conducted through standard XML “topics” (Publish and Subscribe Service). The simulations were federated through data exchange through standards such as DIS and HLA. The only integration of the two architectures has been the exchange of standard tactical C2 messages (VMF, USMTF, and others) through SIM-C2 interface translation boxes (“C2 adapters”) to stimulate C2 systems during a training exercise. A new paradigm developed by the SIMCI OIPT was to use the same UTO force structure and network data set used to initialize the Army C4I systems to also initialize the M&S federation. One challenge with this approach was that the level of granularity in the force structure required to initialize the federation was greater than the level of granularity to initialize the C4I network. The entity resolution federation required the force structure

down to the vehicle, aircraft, and billet (“life-form”) and the weapon systems, sensors, and other simulation-relevant equipment mounted on or associated with these entities.

My lab has been involved with developing prototype SOA web services for the ACSIS program to interface a Simulation Initialization Tool/web service with the ACSIS (DPDE) database. We have also developed prototype web services (based on the JC3IEDM) for JRSG pilot projects to access authoritative data sources (DPDE), conduct data translations (mediation), and produce standard XML data initialization products for M&S federation initialization.

**Answer 2:** Don’t start on the technical level. Focus on the conceptual level to avoid structural variances in the federated solution.

**Answer 3:** Simulations generally execute models that are abstractions of real-world processes. The abstractions used in the model have to meet several goals, often competing, and are a compromise in order for the simulation to achieve its purpose. By requiring a simulation to use a particular form of data, the simulation may not be capable of achieving the purpose of the simulation. It is proper to allow particular simulations to use common data, but it would be wrong to require them to use a particular data schema that would be inappropriate for that simulation.

**Answer 4:** Develop a sufficient prototype(s) to show the governance reference model is supportive of the domain. Test the reference model against varying sizes of service level federations to show that the reference model scales or if multiple reference models are necessary to support a variety of scales (numbers and types of services) of service-based implementations.

**Answer 5:** The current environment in both government and industry demands a close examination of investments and project justification. A thorough business case document can help an enterprise acquire approval, reduce resistance, and execute strategy. Business cases can be strategic or financial, but should include the business case objectives and summary, an examination of alternatives, the financial metrics, supporting arguments, a high-level project schedule and significant milestones, and a discussion of the assumptions and risks. It must also address hard and soft benefits, with both stated in the business context. Further, a business case should address the highest-priority mission goals, whether those are cost savings, competitive advantage, governance, compliance, user experience, or service offerings. The exercise of creating a concise business case will assist the organization to understand the strategic goals, prioritize benefits, socialize the project, gather requirements, predict costs, consider alternatives, and monitor progress.

**Answer 6:** Adopting SOA requires more than just a technology shift. Policies to encourage desirable behavior among employees must be part of your SOA governance. Specific areas that need to be considered include

- Assigning and empowering employees who are responsible for driving process improvement, often called process officers (SOA is about improving business processes, thus someone needs to be responsible for making it happen.)
- Developing the skills necessary for architecting, building, testing, and deploying services and service-oriented applications

- Creating incentives to encourage the building of sharable services and the reuse of existing services
- Forming an enterprise architecture group to drive adoption of EA disciplines and SOA in particular
- Creating a group that is specifically tasked with governing the SOA road map

Typically, the SOA governance group consists of representatives from EA, the different lines of business, and finance. Failure to address organizational and change management issues will lead to slow SOA adoption that lacks coherence, because employees aren't empowered (through organizational structure, training, and incentives) and aren't held accountable for delivering on SOA benefits.

**Answer 7:** Some governance processes may be automated, such as using tools to make sure that WSDLs for services are WS-I compliant. The more governance processes can be automated; the easier it is to scale enterprise-wide SOA efforts. Some governance processes have to be manual, but must be employed to ensure that everyone is moving in the same direction. SOA projects that are left ungoverned generally end up creating a junk drawer of services that leave an enterprise architect group no better off than before it implemented an SOA. When implementing governance policies, a best practice is to make education about the governance process and policies primary, and the actual enforcement secondary.

**Answer 8:** Need to consider whether services always execute on behalf of some user or user role or whether a service can act as an autonomous agent acting on behalf of the enterprise or some community of interest. Additionally, since applications from across

the organization access the service applications, identity management and security enforcement that can manage across boundaries is critical. Clearly, a security policy must be enforceable.

**Answer 9:** The reference model should use common interoperability standards wherever available. Application interoperability is typically based on SOAP and WSDL contracts. Policy interoperability should be based on UDDI and should leverage common policy mapping, support for Web Services Policy Framework (WS-Policy), Web Services Policy Attachment (WS-Policy Attachment), and taxonomies. The enterprise should enforce policy at both design and run-time by ensuring services are not built or deployed that are not compliant and by using platforms when possible and intermediaries as necessary. An example of platform enforcement is using Web Services Security (WS-Security) implementation to enforce the authentication policy. An example of intermediary-based enforcement is using an intermediary to implement a policy that a platform cannot enforce. Finally, run-time and design time policy enforcement must be synchronized.

## **APPENDIX B: FACTORS & IMPACTS**

Table 22: Factor – Incorrect data services and solutions

1	
Name:	Data services and solutions are built that do not meet the needs of the enterprise
Category:	Organizational
Description:	Organizations are finding it difficult develop data services with causing disruptions in the development lifecycle.
Flexibility and Changeability:	As the architecture matures and as more data services become available, this factor will be more important.
Impact:	Impacts interfaces to data developers and processes, organization's own development and integration processes.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 2.</li> <li>• Question 2, Response 4.</li> <li>• Question 4, Response 8.</li> <li>• Question 4, Response 9.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> </ul>

Table 23: Factor - Inconsistent approach

2	
Name:	Inconsistent approach to discovery, consumption, identification, design, development, implementation, and management of data services and solutions
Category:	Organizational
Description:	Organizations are finding it difficult to have consistent approaches to lifecycle activities for data services in an environment.
Flexibility and Changeability:	As time progresses, as the architecture matures, and as more data services become available, this factor will become more and more important.
Impact:	Impacts data service lifecycle cost, budget, and schedule.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 5.</li> <li>• Question 3, Response 6.</li> <li>• Question 4, Response 9.</li> <li>• Question 6, Response 8.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> </ul>



Table 24: Factor - SOA governance approach

3	
Name:	SOA governance approach is not being properly communicated throughout the organization
Category:	Organizational
Description:	Organizations do not have appropriate mechanisms in place for communicating data service governance
Flexibility and Changeability:	As the SOA architecture expands it will become increasingly important to communicate governance at all levels in the organization.
Impact:	Impacts to SOA environment and data service processes, policies, standards, metrics, behaviors, and security.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 7.</li> <li>• Question 3, Response 5.</li> <li>• Question 4, Response 1.</li> <li>• Best Practice – Vision and Leadership.</li> </ul>

Table 25: Factor - Data services have undocumented ownership

4	
Name:	Data services have undocumented ownership
Category:	Organizational
Description:	Services developed in current SOA environments typically are unfunded (ad hoc) and little trace of ownership and sustainment.
Flexibility and Changeability:	As data services are developed, it will become increasingly more important to ensure proper funding for data service lifecycle and fully documented data service ownership with accountability.
Impact:	Impacts the data service consumers upon using the data service to build common data sets.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 8.</li> <li>• Question 3, Response 1.</li> <li>• Question 5, Response 7.</li> <li>• Question 6, Response 8.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> </ul>

Table 26: Factor - Unapproved data services are being deployed

5	
Name:	Unapproved data services are being deployed
Category:	Organizational
Description:	Data services that are deployed without proper approval mechanisms risk building useless data sets.
Flexibility and Changeability:	Data service deployment approval is essential to ensure integrity of data services for building data sets.
Impact:	Impact to all data services and consumers of data set results.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 6.</li> <li>• Question 6, Response 8.</li> <li>• Best Practice – Acquisition and Behavior.</li> </ul>

Table 27: Factor - Data services created do not adhere to governance policies

6	
Name:	Data services created do not adhere to governance policies
Category:	Organizational
Description:	Organizations creating data services in an SOA environment do not have readily available policies, standards, and processes to adhere to.
Flexibility and Changeability:	Policies provide the foundation and framework for SOA and enable the organization to build it better, faster, and cheaper.
Impact:	Failure to enact policies will result in duplicated effort, data services that are not reusable (because they will not “plug-in” together), and data services that suffer from poor reliability.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 2.</li> <li>• Question 2, Response 4.</li> <li>• Question 3, Response 2.</li> <li>• Question 4, Response 9.</li> <li>• Best Practice – Policy and Security.</li> <li>• Best Practice – Acquisition and Behavior.</li> </ul>

Table 28: Factor - Data services are not designed, built, and run in a secure manner

7	
Name:	Data services are not designed, built, and run in a secure manner
Category:	Technological
Description:	Organizations are finding that many data services and associated data sets are not secured. Furthermore, there is no mechanism for publishing and consuming classified data.
Flexibility and Changeability:	Security provides protection and authentication of data services and data access privileges. As data services and data sets become more complex, this factor will continue to be important.
Impact:	Failure to secured data services and data sets; as well as, the policies, processes, and metrics associated with the SOA environment may lead to data leaks to unauthorized users.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 3.</li> <li>• Question 5, Response 1.</li> <li>• Question 6, Response 8.</li> <li>• Best Practice – Policy and Security.</li> </ul>

Table 29: Factor - Changes to data services are not managed

8	
Name:	Changes to data services are not managed
Category:	Organizational
Description:	Organizations are finding that changes to data services that are designed, developed, published, and consumed are not being managed properly (i.e. version control, timely integration, policy validation, etc.).
Flexibility and Changeability:	The process to migrate/change data services needs to be flexible for future functional extension of the service. However, a management process must be in place to record accountability and ensure integrity of the service.
Impact:	Impacts to the overall integrity of the SOA environment when data services are not properly managed for consistent and valid use.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 6.</li> <li>• Question 6, Response 8.</li> <li>• Best Practice – Acquisition and Behavior.</li> </ul>

Table 30: Factor - Data services are not managed in a scalable way

9	
Name:	Data services are not managed in a scalable way
Category:	Product
Description:	Organizations are finding that data services being developed often are not scaled to the SOA environment. Aggregated data service silos are too big (causing performance issues) or are of little value.
Flexibility and Changeability:	Data services must be developed per strict guidelines in order to meet the requirement of the SOA environment and consumer data needs.
Impact:	Impacts to the overall performance of the SOA environment, and ability to discover and access data in a timely manner.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 7.</li> <li>• Question 4, Response 4.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> </ul>

Table 31: Factor - Data service developers cannot easily publish and discover services

10	
Name:	Data service developers cannot easily publish and discover services
Category:	Technological
Description:	Organizations are finding it difficult to deploy new data services and locate existing data services.
Flexibility and Changeability:	As more data services are developed, this factor becomes increasingly more important.
Impact:	Too many data services without publish and discovery mechanisms in place will be time consuming and error-prone for consumers and providers.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 5.</li> <li>• Question 4, Response 4.</li> <li>• Best Practice – Acquisition and Behavior.</li> <li>• Best Practice – Implementation and Operations.</li> </ul>

Table 32: Factor - SOA governance controls and policies

11	
Name:	SOA governance controls and policies either do not exist or are ineffective
Category:	Organizational/Technological
Description:	There are few mechanisms that provide policies and controls for data services.
Flexibility and Changeability:	This factor will always be an issue; however, there is more being done to develop common controls and exception policies. The SOA environment and governance model should be adaptive to updates.
Impact:	Impacts how data services react to publisher and consumer query transactions.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 9.</li> <li>• Question 3, Response 9.</li> <li>• Best Practice – Policy and Security.</li> </ul>

Table 33: Factor - SOA governance roles and responsibilities

12	
Name:	Appropriate and pragmatic SOA governance roles, responsibilities, and authority are not understood and being executed in an unacceptable manner
Category:	Organizational
Description:	Organizations are finding that there are no documented roles, responsibilities, or authority policies in place.
Flexibility and Changeability:	This factor will become increasingly more important as data services and the SOA environment expands. Models can be put into place that provides direction for establishing roles, responsibilities, and authority for data services.
Impact:	Data services and the SOA environment will be impacted in roles, responsibilities, and authority are not understood and executed properly.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 6.</li> <li>• Question 4, Response 7.</li> <li>• Question 5, Response 1.</li> <li>• Question 6, Response 6.</li> <li>• Best Practice – Vision and Leadership.</li> </ul>

Table 34: Factor - Little vitality in the governance process

13	
Name:	Little vitality in the governance process
Category:	Organizational
Description:	SOA governance is not maturing as the SOA capabilities of the organization mature.
Flexibility and Changeability:	Building a common model for setting up, executing, and sustaining data services and compliancy will be invaluable to SOA governance maturation as capabilities mature and changed over time.
Impact:	The data services and whole SOA environment will be impacted.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 9.</li> <li>• Question 4, Response 4.</li> <li>• Question 5, Response 9.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> </ul>

Table 35: Factor - Understanding current governance structures

14	
Name:	Understanding current governance structures
Category:	Organizational/Technological
Description:	Typically governance is a side function of a SOA-based environment, or most likely, not even addressed for most environment. Governance structures are not understood in many SOA-based implementations.
Flexibility and Changeability:	Governance must be modeled and integrated throughout the SOA environment. A governance model should drive data service lifecycle.
Impact:	Impact is on governance of data services and associated policies, standards, processes, security, metrics, roles and responsibilities.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 1.</li> <li>• Question 2, Response 7.</li> <li>• Question 3, Response 5.</li> <li>• Best Practice – Policy and Security.</li> </ul>

Table 36: Factor - Assessing SOA governance maturity

15	
Name:	Assessing SOA governance maturity
Category:	Product
Description:	SOA governance needs to be assessed and measured in order to improve processes and life cycle design/development of data services.
Flexibility and Changeability:	Building a common metrics model for assessment of SOA governance and data services.
Impact:	The data services are impacted based on type of metrics to be collected and presented. Impacts to SOA environment performance due to additional processing needed for metrics collection. Though lack of metrics may lead to little understanding of the value of governance model and possible improvements in infrastructure.
Reference:	<ul style="list-style-type: none"> <li>• Question 5, Response 2.</li> <li>• Question 5, Response 3.</li> <li>• Question 5, Response 9.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> <li>• Best Practice – Acquisition and Behavior.</li> <li>• Best Practice – Implementation and Operations.</li> </ul>

Table 37: Factor - Developing SOA governance

16	
Name:	Developing SOA governance vision and strategy, scope, principles, and roadmap
Category:	Organizational
Description:	SOA governance elements must be in place before design, development, and integration of SOA infrastructure and data services.
Flexibility and Changeability:	A SOA governance model needs to be developed based on a reference model that provides common governance elements and drives SOA vision, strategy, scope, principle, and roadmap.
Impact:	The impact of not having a governance model and reference model will impact data service lifecycle and overall SOA organizational goals and environment.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 7.</li> <li>• Question 5, Response 7.</li> <li>• Best Practice – Vision and Leadership.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> </ul>

Table 38: Factor - Data service identification and appropriate reuse

17	
Name:	Data service identification and appropriate reuse
Category:	Product
Description:	Organizations are finding it difficult to identify data services in SOA-based environments. There is little documentation and processes that enable reuse of the services.
Flexibility and Changeability:	Include processes and behavioral mechanisms in the governance model that allow identification of data services and their reuse applicability.
Impact:	The organizational budget, schedule, and data service usage will be impacted.
Reference:	<ul style="list-style-type: none"> <li>• Question 4, Response 6.</li> <li>• Question 4, Response 7.</li> <li>• Best Practice – Acquisition and Behavior.</li> <li>• Best Practice – Implementation and Operations.</li> </ul>



Table 39: Factor - Demonstrating the quality of SOA governance solutions

18	
Name:	Demonstrating the quality of SOA governance solutions
Category:	Product
Description:	Be able to measure the quality (reliability, availability, reusability, etc.) of data services and the overall SOA governance model.
Flexibility and Changeability:	Collect and maintain Quality of Service (QoS) metrics for data services based on metrics governance model.
Impact:	SOA governance, infrastructure, and data service lifecycle improvement and maturation are impacted by quality measures.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 4.</li> <li>• Question 5, Response 7.</li> <li>• Best Practice – Acquisition and Behavior.</li> </ul>

Table 40: Factor - Data service solution portfolio management

19	
Name:	Data service solution portfolio management
Category:	Organizational
Description:	Identify and assess applicability and QoS of data service solutions.
Flexibility and Changeability:	Build a behavioral model within the SOA governance model that allows organizations to rate data services based on reusability, applicability, reliability, etc.
Impact:	This factor impacts organizational cost and schedule when using data services with little information indicating applicability and QoS.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 6.</li> <li>• Question 4, Response 8.</li> <li>• Question 5, Response 4.</li> <li>• Best Practice – Policy and Security.</li> </ul>

Table 41: Factor - Ensuring data services satisfy business requirements

20	
Name:	Ensuring data services satisfy organizational requirements
Category:	Technological
Description:	Data services must be able to meet organizational and functional requirements.
Flexibility and Changeability:	Build model that includes data service portfolio management and traceability of service functionality to requirements.
Impact:	This impact is to the SOA environment and organizations if superfluous data services with no requirement traceability are published to the registry.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 9.</li> <li>• Question 4, Response 1.</li> <li>• Question 5, Response 5.</li> <li>• Best Practice – Vision and Leadership.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> </ul>

Table 42: Factor - Lack of data service interoperability

21	
Name:	Lack of data service interoperability
Category:	Technological
Description:	SOA Governance model must support interoperability and integration of data services.
Flexibility and Changeability:	Reference model needs to be common but generic so not to enforce specific implementation, but allow for many common standards, processes, etc. that support data service aggregation and interoperability.
Impact:	Data services are impacted heavily if data service is dependent on another data service to complete a data set function.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 1.</li> <li>• Question 3, Response 7.</li> <li>• Question 4, Response 2.</li> <li>• Question 6, Response 9.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> <li>• Best Practice – Implementation and Operations.</li> </ul>

Table 43: Factor - Uncontrolled proliferation of data services

22	
Name:	Uncontrolled proliferation of data services
Category:	Technological
Description:	Data services that are developed without any management or control.
Flexibility and Changeability:	Governance model must address how data services portfolio and lifecycles will be managed.
Impact:	Data service registry may become flooded and organizations may be unaware of the intent of the various data services.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 8.</li> <li>• Question 3, Response 8.</li> <li>• Best Practice – Acquisition and Behavior.</li> </ul>

Table 44: Factor - Cross-organization coordination

23	
Name:	Cross-organization coordination
Category:	Organizational
Description:	Data services need to be governed in a conformed environment, and the governance model should provide guidance to stakeholders on how to use data services.
Flexibility and Changeability:	Service level agreement processes need to be put into place for organizations to coordinate data service and SOA infrastructure interoperability.
Impact:	This factor impacts organizations and their use of data services to build data sets.
Reference:	<ul style="list-style-type: none"> <li>• Question 3, Response 6.</li> <li>• Question 4, Response 5.</li> <li>• Best Practice – Vision and Leadership.</li> <li>• Best Practice – Strategy and Roadmap Development.</li> </ul>

Table 45: Factor - Data service metrics and quantifiable measures

24	
Name:	Data service metrics and quantifiable measures
Category:	Organizational/Technological
Description:	Organizations need to be able to measure and review data service performance and quality.
Flexibility and Changeability:	Governance model should provide guidance on how metrics may be applied to data services and the overall SOA infrastructure.
Impact:	Organizations will be impacted by cost and schedule if unknown issues are not discovered by collecting and evaluating metrics.
Reference:	<ul style="list-style-type: none"> <li>• Question 2, Response 3.</li> <li>• Question 3, Response 4.</li> <li>• Question 3, Response 8.</li> <li>• Question 5, Response 3.</li> <li>• Question 5, Response 4.</li> <li>• Question 5, Response 8.</li> <li>• Best Practice – Acquisition and Behavior.</li> </ul>

## **APPENDIX C: SOLUTIONS & STRATEGIES**

Table 46: Issue - Adoption of data service governance reference model

1		
Name:	Adoption of data service governance reference model	
Description:	For an organization to be able to adopt the policies, processes, standards, etc., and invest the effort required to re-engineer existing and future data services based on a governance reference model, a number of concerns will have to be addressed. Specifically it must be shown that the reference model allows service reuse, mitigates the risks of black box service use, allows the organization to effectively leverage existing and future infrastructure, and supports the construct and environment required to interface with legacy systems and use legacy data services.	
Influencing Factor(s):	No.	Name
	2	Inconsistent approach
	3	SOA governance approach
	11	SOA governance controls and policies
	16	Developing SOA governance
Solution:	Use of the approved governance artifacts, from the SOA governance model, will reduce data service risk and lower costs, by reducing the number and complexity of design activities in the data service. Organization governance models may be based on standard SOA governance models or industry governance models. All SOA governance solutions should be created based on the organization's SOA governance model.	
Strategy:	<b><i>Reference and adopt industry best practices and integrate with organizational best practices and specific needs:</i></b> Create a single SOA governance model that will be tailored to provide interaction between the data services. This reference model will present a framework for designing and developing a data service to call into and receive data sets from the SOA-based infrastructure.	

Table 47: Issue - Implementing data service governance

2		
Name:	Implementing data service governance	
Description:	Governance requires an appropriate organizational structure and identification of who has authority to make governance decisions.	
Influencing Factor(s):	No.	Name
	3	SOA governance approach
	13	Little vitality in the governance process
	16	Developing SOA governance
	20	Ensuring data services satisfy business requirements
Solution:	Ensure that an organization is willing to develop and support a needed data service long-term, especially if data services may be used across organization activities. Data services developed on an ad hoc basis may not be officially supported for defects, conformance, enhancement, and performance.	
Strategy:	<p><b><i>Develop a governance framework:</i></b> Governance framework provides the agreement to be abided by data service stakeholders. Processes define the framework that in turn forms the structure for procedures.</p> <p><b><i>Identify data service requirements:</i></b> Data service requirements are defined by data service stakeholders, considered by data service governance body, and satisfied the data service governance activities.</p> <p><b><i>Charter data service governance body:</i></b> The data service governance body considers data service requirements, initiates and champions data service governance, and generates consistent policies.</p> <p><b><i>Identify data service stakeholders:</i></b> Data service stakeholders define data service requirements, agree to abide by the governance framework, and exercise authority over the data service governance body.</p> <p><b><i>Identify policies and processes:</i></b> Policies are defined by standards, regulation, and rules, and establish processes. Processes define the changing of the governance framework, and are elaborated by procedures.</p>	

Table 48: Issue - Executing data service governance

3		
Name:	Executing data service governance	
Description:	To carry out data service governance, stakeholders charter a governance body to promulgate the rules needed to make the policies operational. The governance body coordinates with governance processes for its rule-making process and other functions. Whereas governance is the setting of policies and defining the rules that provide an operational context for policies, the operational details of governance are delegated by the governance body to management. Management generates regulations that specify details for rules and other procedures to implement both rules and regulations.	
Influencing Factor(s):	No.	Name
	11	SOA governance controls and policies
	12	SOA governance roles and responsibilities
	13	Little vitality in the governance process
	23	Cross-organization coordination
Solution:	Ensure proper execution of governance by communicating SOA governance value, and appropriate SOA governance policies and processes.	
Strategy:	<p><b>Define management delegation:</b> Management implements and generates regulations, interprets rules, and identifies and implements standards.</p> <p><b>Mandate and interpret rules:</b> Rules allow policies to be operational.</p> <p><b>Identify and implement standards and regulations:</b> Standards guide the implementation of regulations, and regulations provides details of mandated processes to realize rules.</p> <p><b>Generate and execute policies:</b> Policies are generated by the data service governance body and made operational by rules.</p>	



Table 49: Issue - Enforcing data service governance compliance

4		
Name:	Enforcing data service governance compliance	
Description:	<p>Metrics are those conditions and quantities that can be measured to characterize actions and results. Rules and regulations must be based on collected metrics or there will be no way for management to assess compliance. The metrics are available to the data service stakeholders, and the data service governance body. Thus, what is measured and the results of measurement are clear to everyone. The data service governance body defines specific enforcement responses, such as what degree of compliance is necessary. It is up to management to identify compliance shortfalls and to initiate the enforcement process</p>	
Influencing Factor(s):	No.	Name
	5	Unapproved data services are being deployed
	6	Data services created to not adhere to governance policies
	9	Data services are not managed in a scalable way
	13	Little vitality in the governance process
Solution:	Ensure high-quality data services and conditions are met that have been expressed to achieve stated goals.	
Strategy:	<p><b><i>Initiate actions that result in enforcement:</i></b> Management initiates the enforcement process. Enforcement applies incentives or penalties to data service stakeholders, and defines options and responses for the data service governance body.</p> <p><b><i>Apply incentives or penalties against data service stakeholders:</i></b> Metrics inform management of data service stakeholder activities. The data service governance body defines specific enforcement responses based on degree of necessary compliancy.</p> <p><b><i>Define metrics available to stakeholders, governance body, and management:</i></b> Metrics are available to data service governance body, data service stakeholders, and management.</p> <p><b><i>Management guided by policies and processes:</i></b> Metrics provide measureable quantities for policies and processes, and informs management.</p>	

Table 50: Issue - Data service protection via security rules

5		
Name:	Data service protection via security rules	
Description:	Security must consider both transport and message level protection because distributed access, including whole range or intermediary, are common in SOA (some intermediary examples include routers, policy enforcers and business process coordinators). Transport level security, such as https, is simple, but it stops at the endpoint, whereas message level security allows headers to be decrypted for routing while keeping content secure and private. Message level security also enables message parts to be handled independently, which is critical for SOA intermediaries to work—and to work securely.	
Influencing Factor(s):	No.	Name
	7	Data services are not designed, built, and run in a secure manner
	12	SOA governance roles and responsibilities
	17	Data service identification and appropriate reuse
Solution:	Ensure correct security levels and risk levels.	
Strategy:	<p><b><i>Empower data service stakeholders with authority:</i></b> Data service stakeholders have an identity that is verified by authentication.</p> <p><b><i>Authenticate data service stakeholder identity and authority:</i></b> Authentication requires authorization that is defined by policies and processes. Authorization includes confidentiality, integrity, and trust elements. Authorization must assess attributes, behavior, and role of data service stakeholders.</p> <p><b><i>Define policy rules and process steps for authorization:</i></b> Data service stakeholders define the policies and processes for authorization.</p>	

Table 51: Issue - Data service enforcement via policies and standards

6		
Name:	Data service enforcement via policies and standards	
Description:	Policies and standards are methods of action selected from among alternatives and in light of given conditions to guide and enforce present and future decisions. Policies and standards apply to the governed data service.	
Influencing Factor(s):	No.	Name
	4	Data services have undocumented ownership
	6	Data services created do not adhere to governance policies
	8	Changes to data services are not managed
	9	Data services are not managed in a scalable way
	18	Demonstrating the quality of SOA governance solutions
	22	Uncontrolled proliferation of data services
	24	Data service metrics an quantifiable measures
Solution:	Ensure data service providers are adhering to current operational and tactical policies and standards established by authority, custom, or general consent as a model.	
Strategy:	<p><b><i>Enforce data service contract defined by policy:</i></b> The data service contract is part of a policy constraint. It is put in force by the enforcement process, reference policy, and is agreed upon by data service stakeholders.</p> <p><b><i>Govern policy constraints:</i></b> A policy constraint is a part of policy, and governed by permission and obligation.</p> <p><b><i>Translate policy from guidelines:</i></b> A policy is translated by guidelines and quantified by metrics. Policy is owned by the data service stakeholder.</p> <p><b><i>Identify metrics to provide measures for policies and standards:</i></b> Metrics provide measurable quantities for policies and standards.</p>	

Table 52: Issue - Data service implementation via processes and procedures

7		
Name:	Data service implementation via processes and procedures	
Description:	Processes and procedures are particular methods for performing tasks. They identify how a data service will be governed.	
Influencing Factor(s):	No.	Name
	1	Incorrect data services and solutions
	2	Inconsistent approach
	10	Data service developers cannot easily publish and discover services
	19	Data service solution portfolio management
	21	Lack of data service interoperability
Solution:	Implement data service steps for design, development, testing, implementation, deployment, and sustainment that conform to policies and standards.	
Strategy:	<p><b><i>Define guidelines based on rules, regulations, and standards:</i></b> A guideline is checked at a checkpoint which is defined by compliance, and is translated into policy. The checkpoint provides inspection for governed processes.</p> <p><b><i>Define governing processes by compliance, communication, and dispensation:</i></b> Governing processes define compliance, communication, and dispensation. Activities execute governing processes and can have checkpoints that are inspected by governed processes.</p> <p><b><i>Define governed processes by data service lifecycle and data service portfolio management:</i></b> Governed processes are defined by lifecycle and portfolio management. Lifecycle is an instantiation of service lifecycle that manages services for the service portfolio management. Service portfolio management is an instantiation of portfolio management and prioritizes services for service lifecycle.</p>	

Table 53: Issue - Data service management via roles and responsibilities

8		
Name:	Data service management via roles and responsibilities	
Description:	Roles and responsibilities articulate a person or group of people responsible for managing the governed data service. It must be clear for each data service who this responsibility party is. Roles and responsibilities should be considered for the SOA implementation at the enterprise level. Depending on the size of the SOA effort and resource constraints, several different roles can be assigned to the same staff person.	
Influencing Factor(s):	No.	Name
	12	SOA governance roles and responsibilities
Solution:	Manage data service roles and responsibilities considered as part of an organization's SOA governance model. Which roles apply will be a function of the governance principles and SOA governance maturity. The role name is not as important as the responsibilities highlighted. Each organization has their own role naming conventions and it is more important to adopt/align the new governance responsibilities with the existing internal structures.	
Strategy:	<p><b><i>Establish roles for data service stakeholders, sponsors, governance body, management, and service lifecycle:</i></b> A role consists of an organizational structure and responsibility.</p> <p><b><i>Create additional custom roles and responsibilities for the organization unique to the business activities:</i></b> An organizational structure is part of a role and may be expanded to include additional roles and responsibilities as needed by the organization.</p> <p><b><i>Identify responsibilities for security, policies, processes, metrics, and behaviors:</i></b> A responsibility has one or more roles assigned to it.</p>	

Table 54: Issue - Data service monitoring via metrics

9		
Name:	Data service monitoring via metrics	
Description:	A metric is a standard of measurement. It is important to put in place the measurements for the success of a governed data service.	
Influencing Factor(s):	No.	Name
	15	Assessing SOA governance maturity
	18	Demonstrating the quality of SOA governance solutions
	24	Data service metrics and quantifiable measures
Solution:	Monitor data services using metrics that provide the technical basis for evaluating the effectiveness of the SOA and determining the order in which data services should be built as it moves towards the architecture vision. Metrics give ways to prioritize data services and determine the largest return on investment (ROI) within an organization.	
Strategy:	<p><b><i>Define metrics for policies, processes, and behaviors:</i></b> Data service stakeholders define metrics for policies, processes, and behaviors.</p> <p><b><i>Guide decisions tracked by compliance measurement:</i></b> Decisions are tracked by compliance measurement and are available to the data service governance body and data service stakeholder. Compliance measurement records measurements with audits, assures decision obligations by enforcement, and assures rules set by conformance.</p> <p><b><i>Provide metrics for management, data service stakeholders, and data service governance body:</i></b> Metrics are set by the data service governance body, and provide values for decisions that measure service level metrics for management.</p>	

Table 55: Issue - Data service motivation via behaviors

10		
Name:	Data service motivation via behaviors	
Description:	Behavior is important to a governance reference model. Supporting distributed data services requires an increased level of social interaction between the different data service stakeholders.	
Influencing Factor(s):	No.	Name
	4	Data services have undocumented ownership
	5	Unapproved data services are being deployed
	15	Assessing SOA governance maturity
	24	Data service metrics and quantifiable measures
Solution:	Emplace incentive and penalty mechanisms for appropriate behaviors for design, development, conformance, sustainment, and use of data services.	
Strategy:	<p><b><i>Determine incentive and penalties based on behavioral service usage:</i></b> Data service stakeholders' usage of data services are recorded as behaviors and patterns that determine incentives and penalties applied to data service stakeholders.</p> <p><b><i>Maintain metrics available to data service stakeholders:</i></b> Incentives and penalties are recorded as quantities for metrics. Metrics are available to data service stakeholders.</p>	

## **APPENDIX D: GOVERNANCE REFERENCE MODEL DESIGN & DOCUMENTATION**



This appendix provides the full description of the governance reference model.

### High Level Conceptual Governance Reference Model

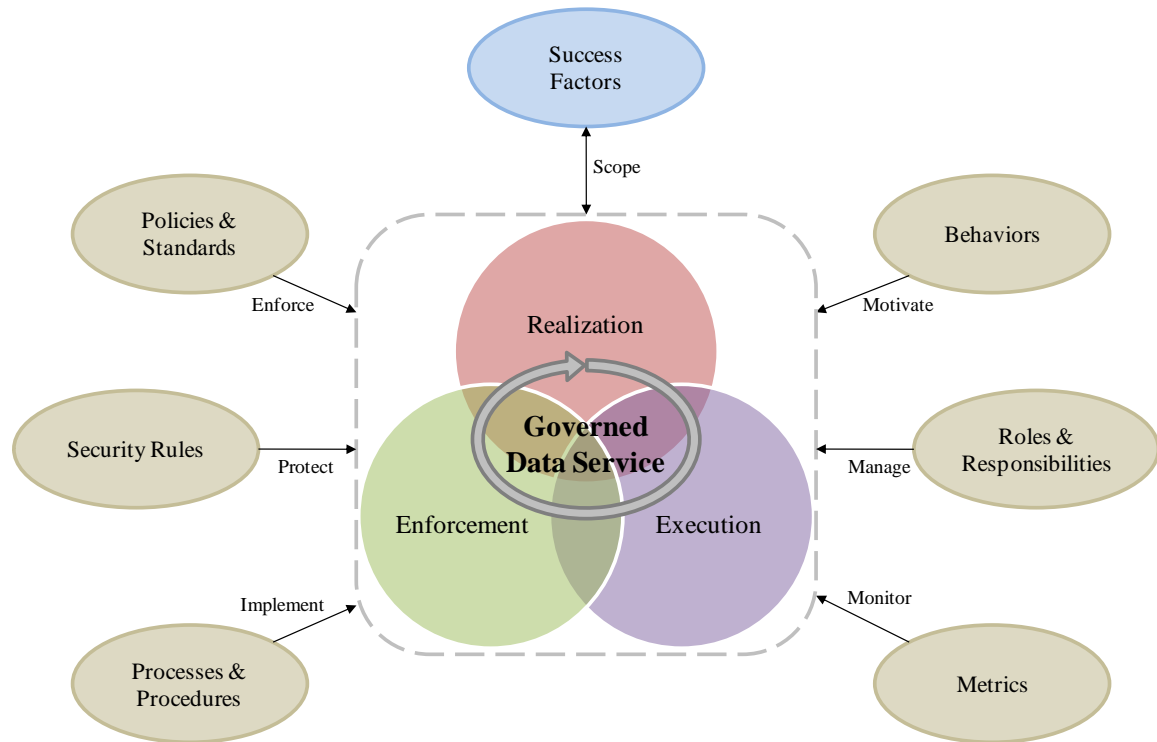


Figure 35: High Level Conceptual Governance Reference Model

Figure 35 illustrates the *revised* high level conceptual governance reference model derived from subject matter expert input, organizational best practices, and prototype results. The model consists of three process stages: Realization, Execution, and Enforcement, and seven threads: Policies & Standards, Security Rules, Processes & Procedures, Behaviors, Roles & Responsibilities, Metrics, and Success Factors.

## Data Service Governance Realization Reference Model

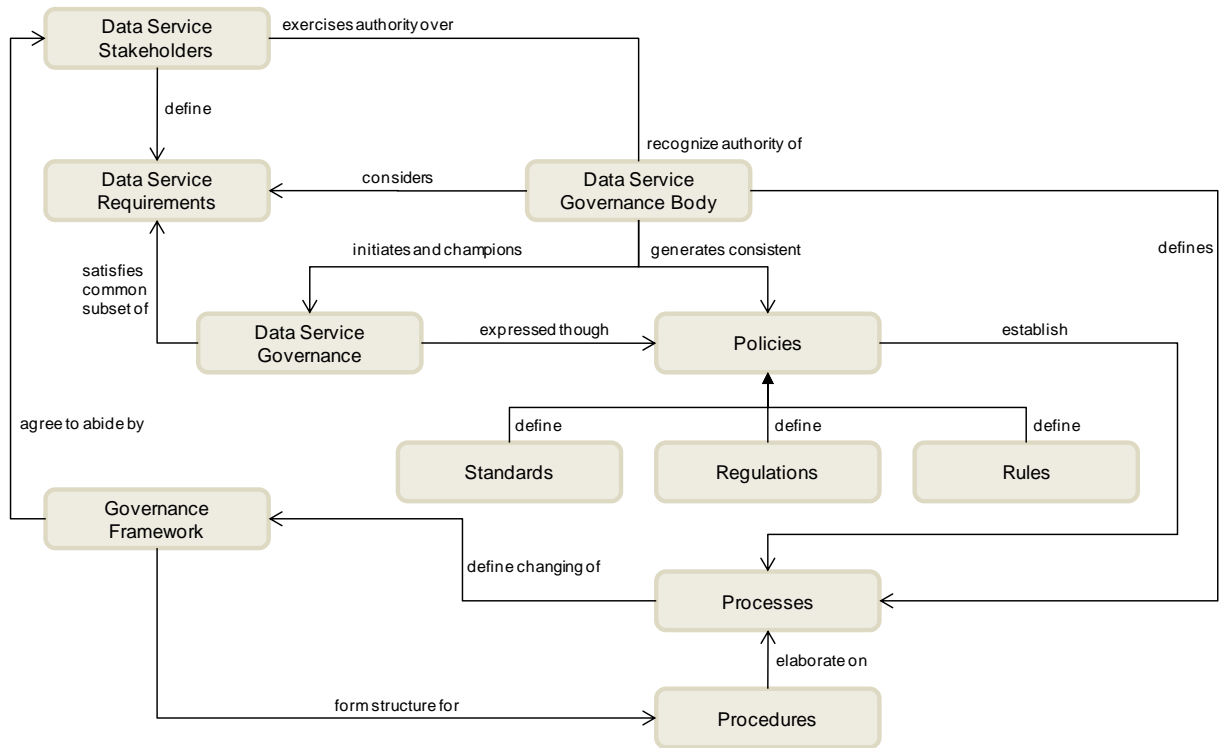


Figure 36: Data Service Governance Realization Reference Model

Figure 36 illustrates the data service governance realization reference model which is a first-order decomposition of the Realization process stage. This stage provides the underlying core governance structure for applying governance in an environment. It is responsible for defining governance and a governance body, establishing policies and processes, and the overall governance structure for stakeholders.

## Data Service Governance Execution Reference Model

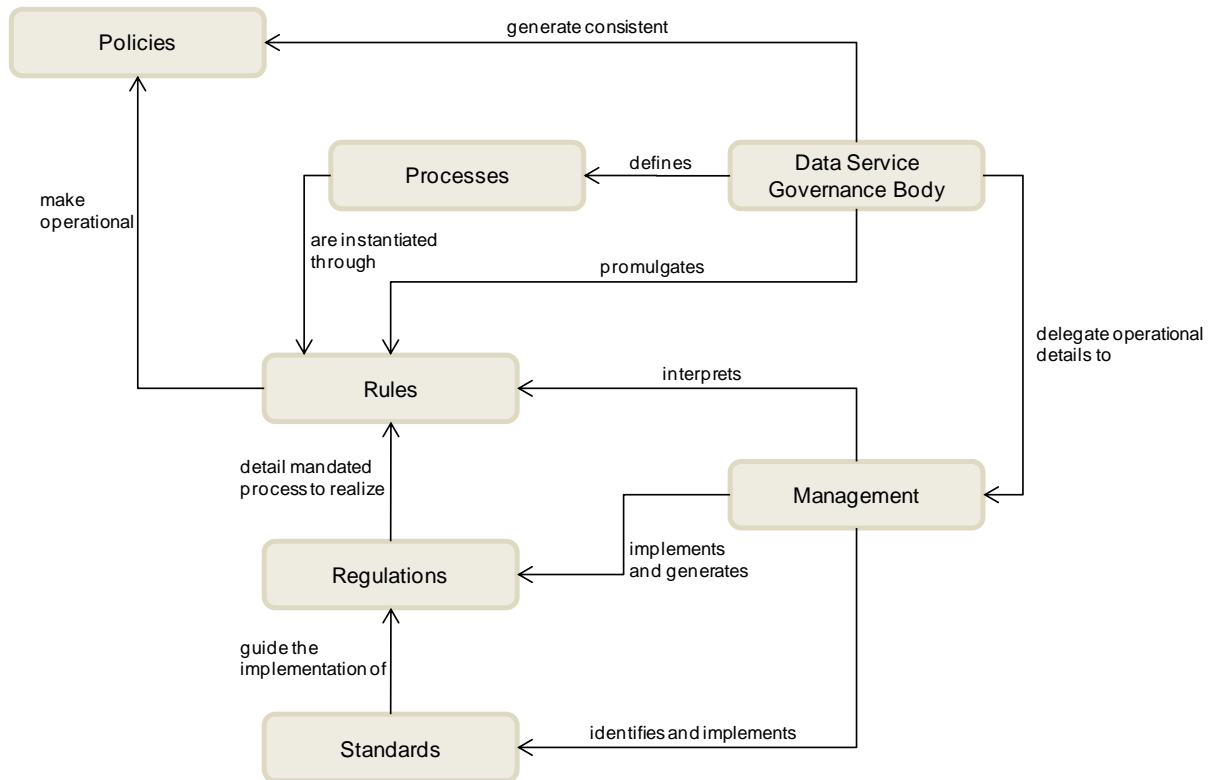


Figure 37: Data Service Governance Execution Reference Model

Figure 37 illustrates the data service governance execution reference model which is a first-order decomposition of the Execution process stage. This stage provides the operational structure for managing the service lifecycle. The diagram illustrates the flow of policies, processes, rules, regulations, and standards from the perspective of the data service governance body and management.

## Data Service Governance Compliance Enforcement Reference Model

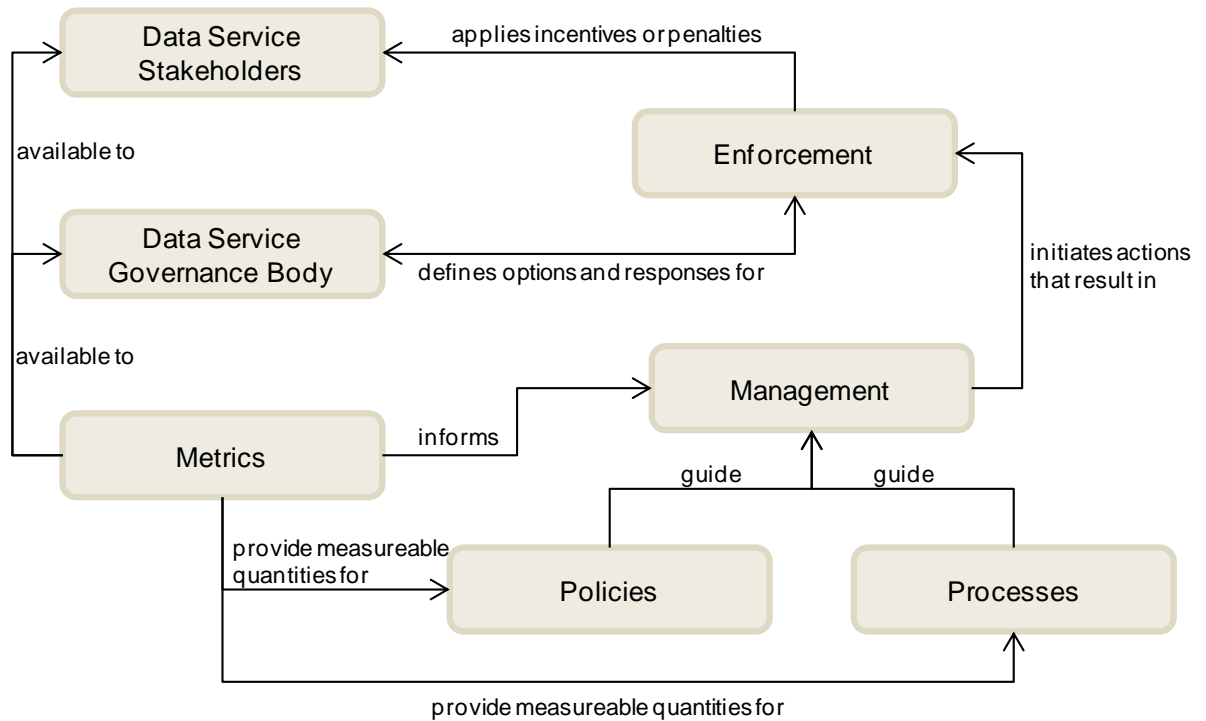


Figure 38: Data Service Governance Compliance Enforcement Reference Model

Figure 38 illustrates the data service governance enforcement reference model which is a first-order decomposition of the Enforcement process stage. This stage provides the conformance structure for ensuring the adherence of a service to the governance model. The diagram illustrates the flow of policies and processes from the perspective management that guides compliance enforcement.

## Data Service Success Factors Reference Model

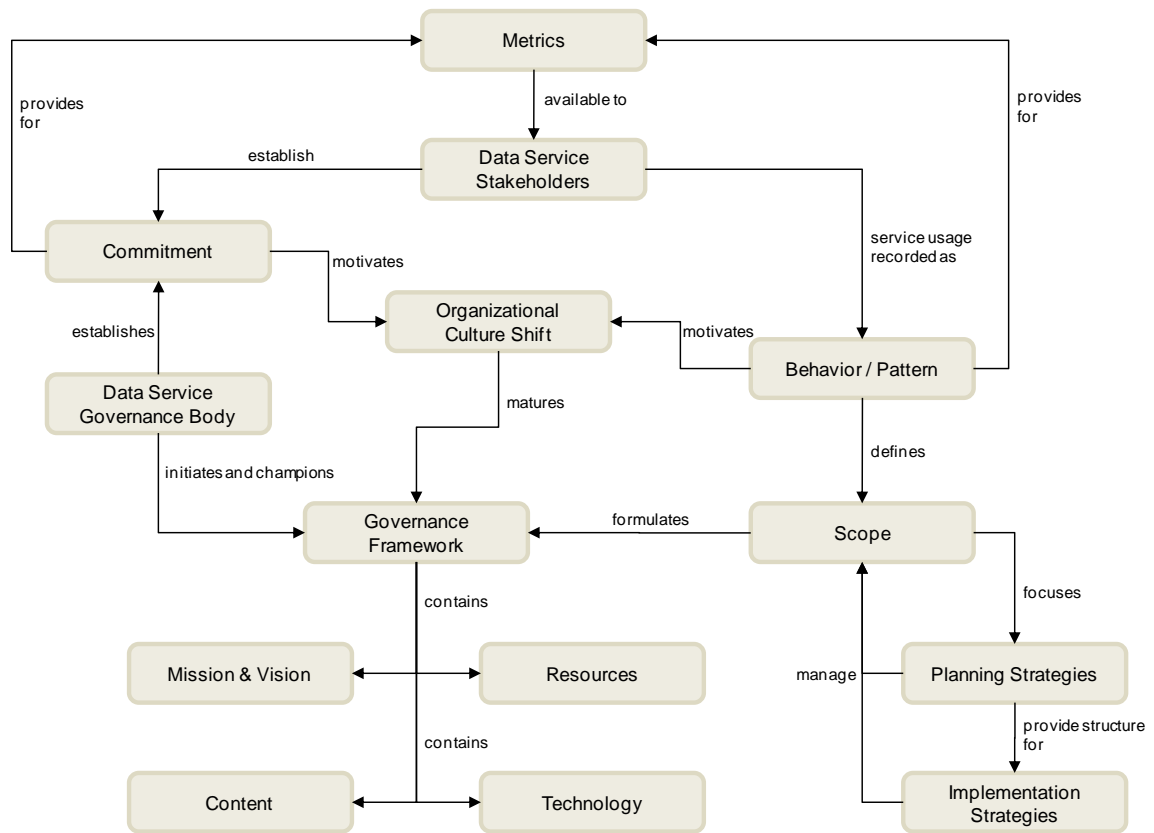


Figure 39: Data Service Success Factors Reference Model

Figure 39 illustrates the data service success factors reference model which is a first-order decomposition of the Success Factors use case thread. This thread provides a bidirectional scoping structure for a service and organization. The diagram illustrates the stakeholder commitment, behaviors/patterns, and organizational culture shift that matures the governance framework driven by scope.

## Data Service Security Rules Reference Model

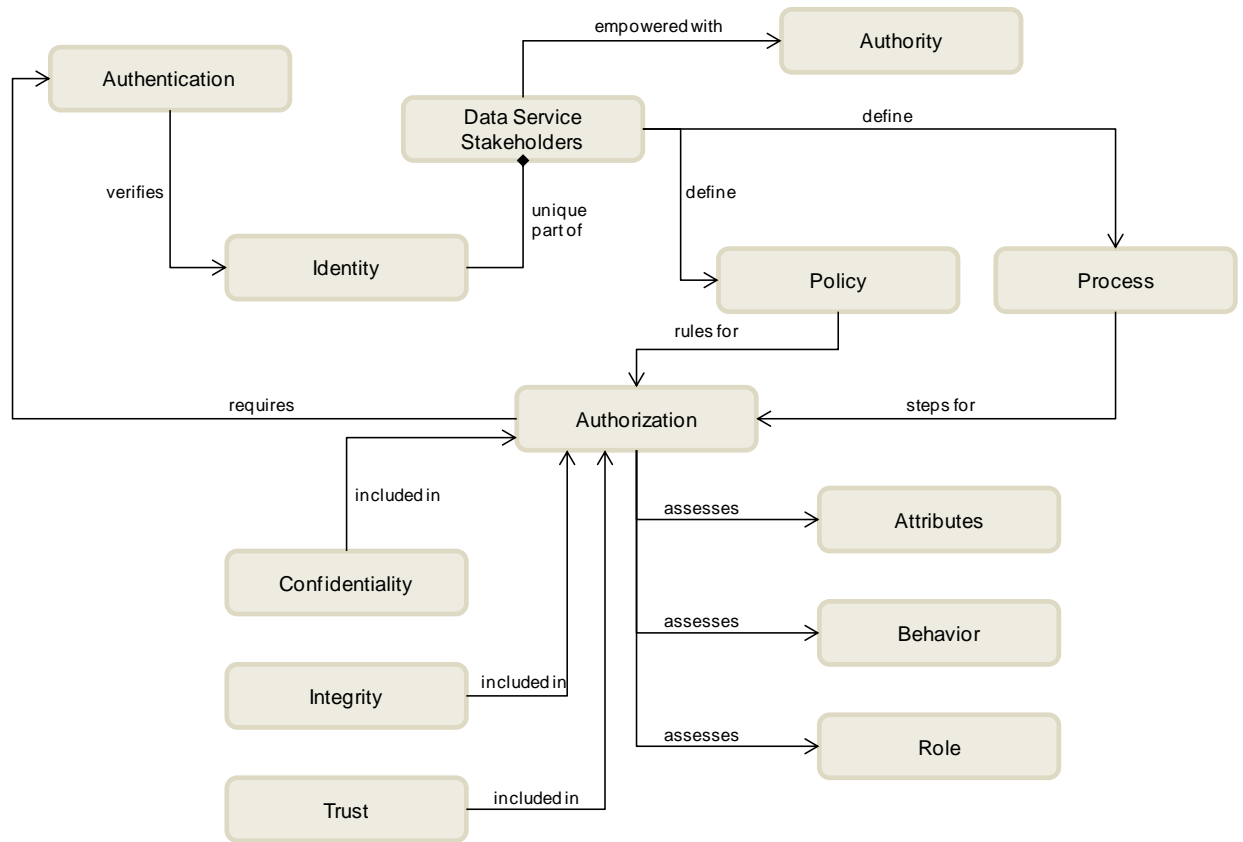


Figure 40: Data Services Security Rules Reference Model

Figure 40 illustrates the data service security rules reference model which is a first-order decomposition of the Security Rules use case thread. This thread provides a protection structure for a service. The diagram illustrates the authority empowered by stakeholders that define authorization policies and processes for identity and authentication.

## Data Service Policies and Standards Reference Model

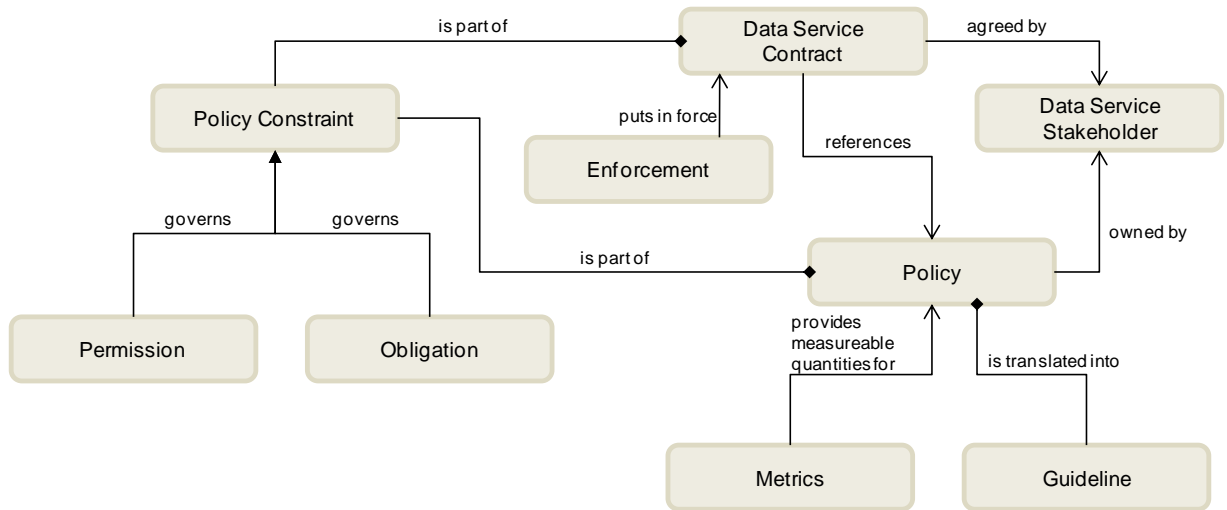


Figure 41: Data Service Policies and Standards Reference Model

Figure 41 illustrates the data service policies and standards reference model which is a first-order decomposition of the Policies and Standards use case thread. This thread provides an enforcement structure for a service. The diagram illustrates the reference of policies and guidelines that enforce data service contracts agreed to by stakeholders.

## Data Service Processes and Procedures Reference Model

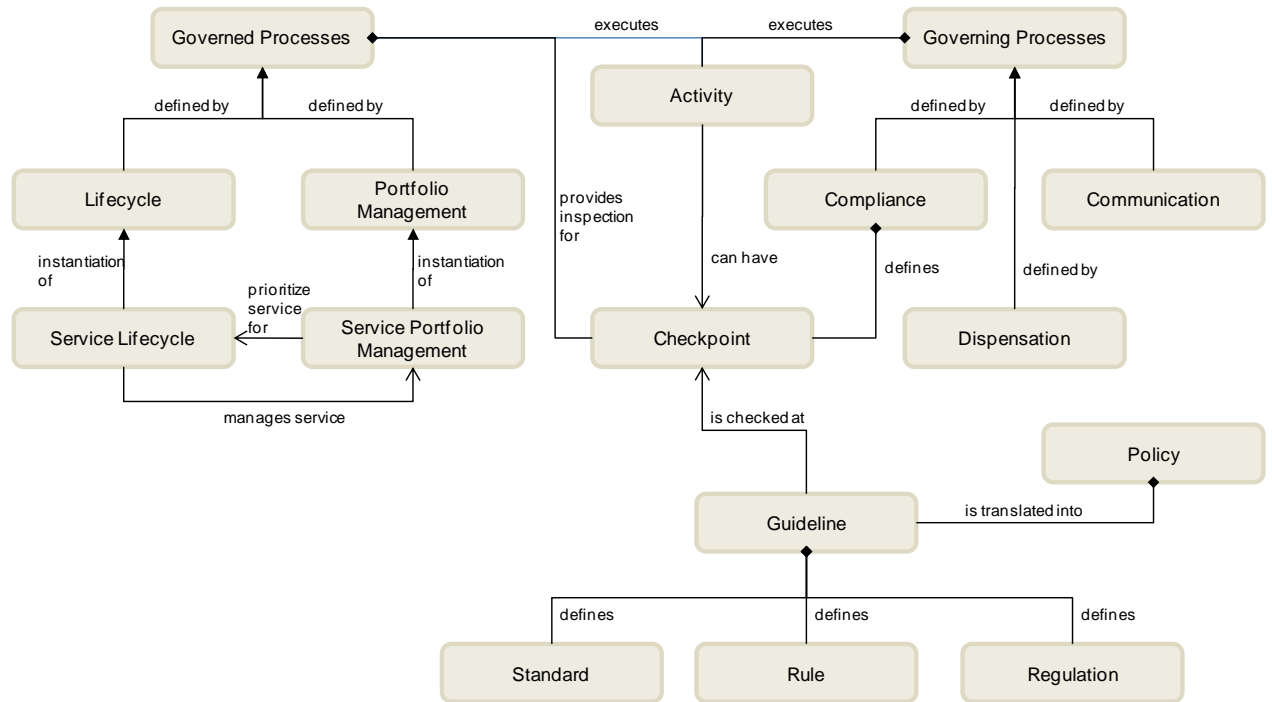


Figure 42: Data Service Processes and Procedures Reference Model

Figure 42 illustrates the data service processes and procedures reference model which is a first-order decomposition of the Processes and Procedures use case thread. This thread provides an implementation structure for a service. The diagram illustrates the lifecycle management of governed processes and compliance, communication, and dispensation of governing processes.



## Data Service Metrics Reference Model

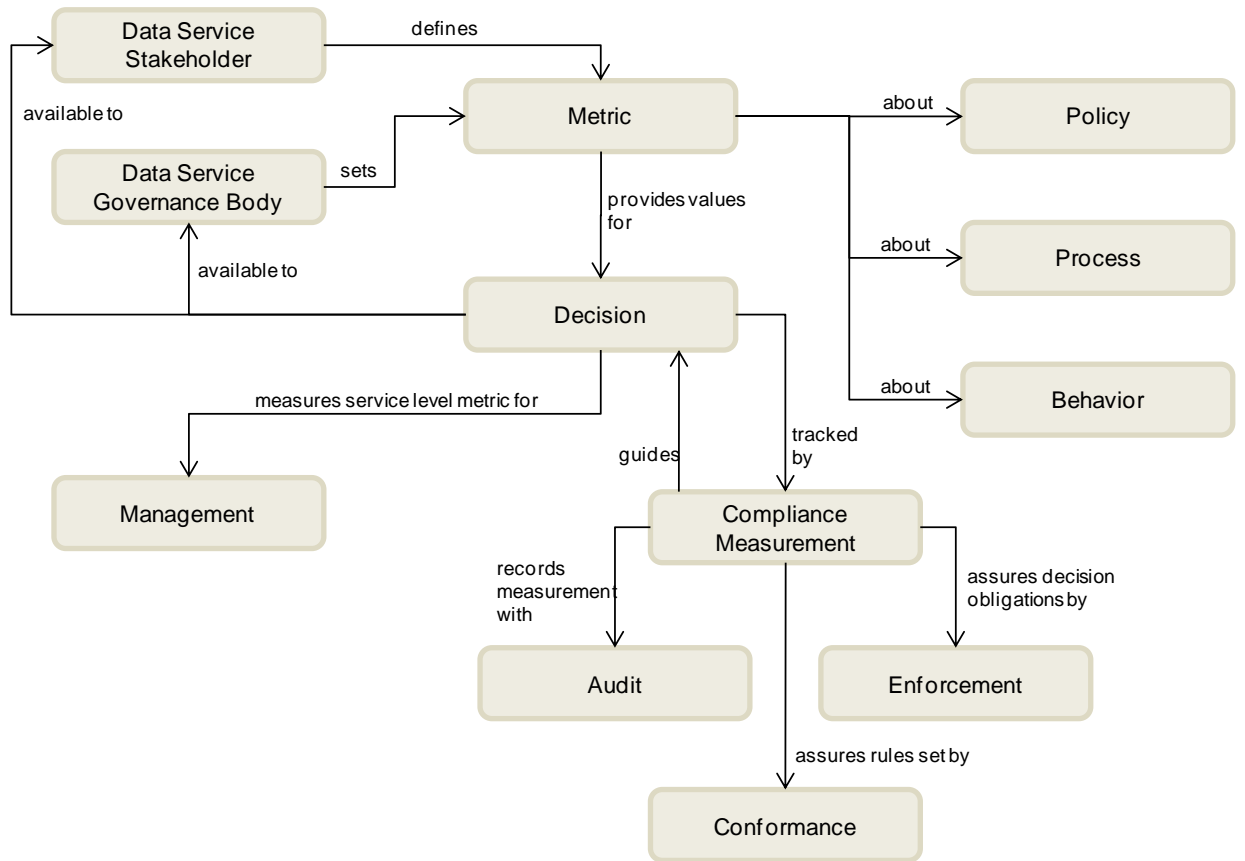


Figure 43: Data Service Metrics Reference Model

Figure 43 illustrates the data service metrics reference model which is a first-order decomposition of the Metrics use case thread. This thread provides a monitoring structure for a service. The diagram illustrates metrics as defined by stakeholders and the governance body. Metrics can monitor policy, process, and behavior, and support management decisions tracked by compliance measurement.

## Data Service Roles and Responsibilities Reference Model

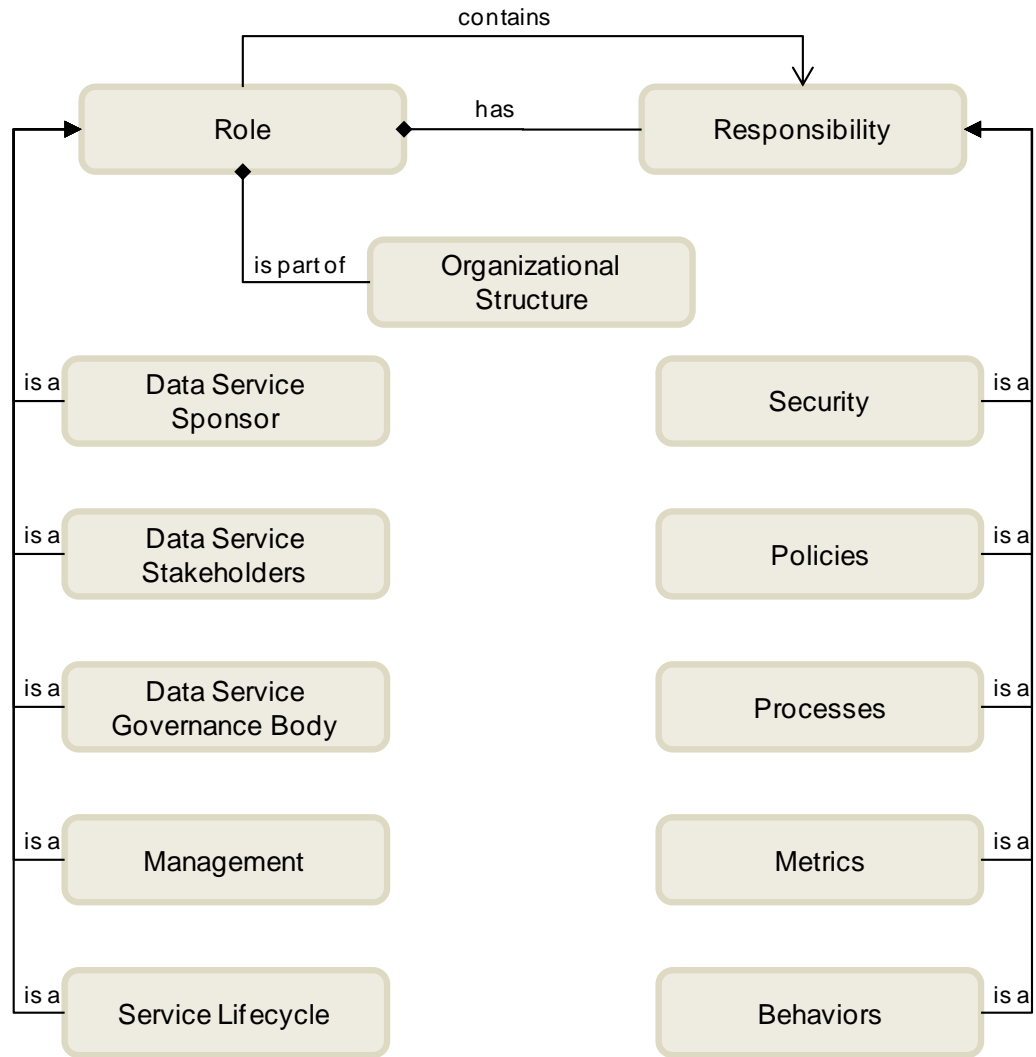


Figure 44: Data Service Roles and Responsibilities Reference Model

Figure 44 illustrates the data service roles and responsibilities reference model which is a first-order decomposition of the Roles and Responsibilities use case thread. This thread provides a management structure for a service.

## Data Service Behaviors Reference Model

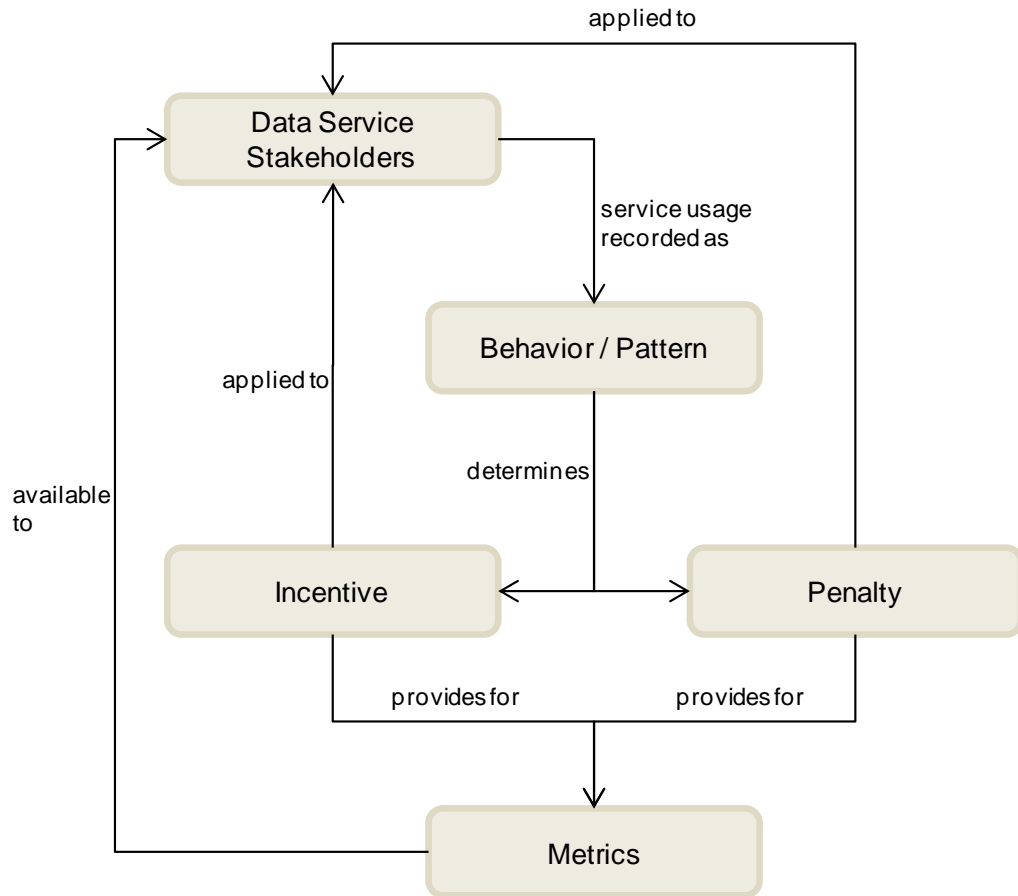


Figure 45: Data Service Behaviors Reference Model

Figure 45 illustrates the data service behaviors reference model which is a first-order decomposition of the Behaviors use case thread. This thread provides a motivation structure for a service. The diagram illustrates the behaviors and patterns of data service usage by stakeholders. Appropriate incentives and penalties are determined based on respective behaviors and patterns, and applied against stakeholders.

## **APPENDIX E: PROTOTYPE DESIGN & DOCUMENTATION**

This appendix provides the full description of the prototype's architecture.

## Data Services Server Architecture

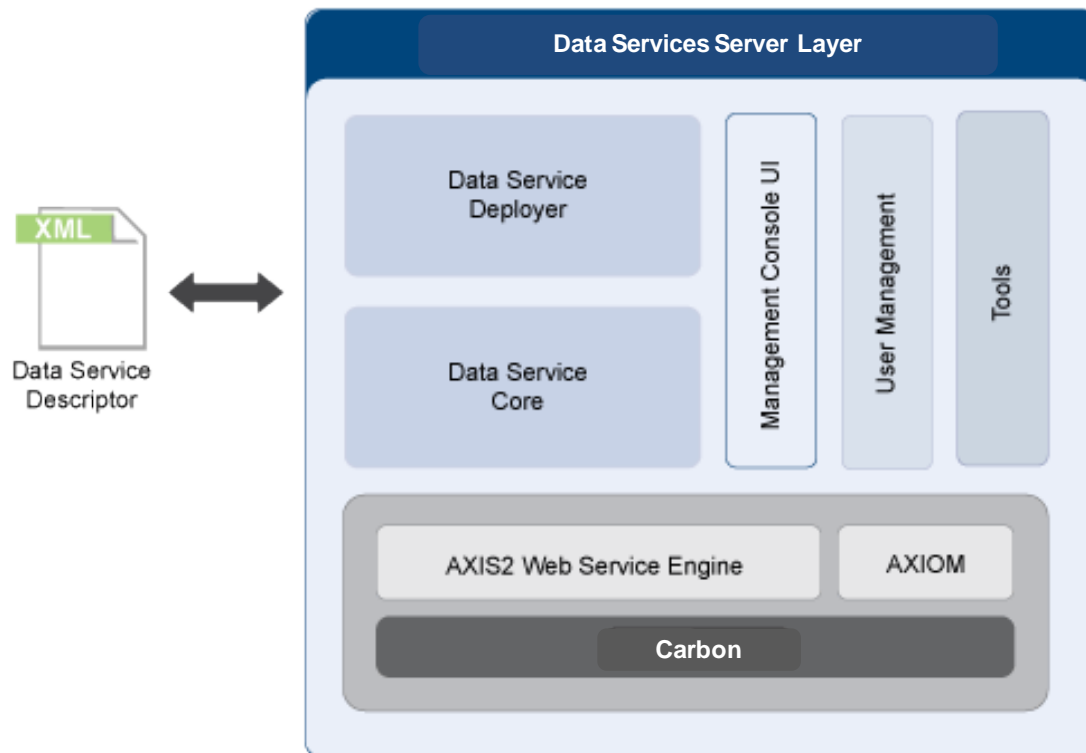


Figure 46: Data Services Server Architecture

The Data Services Server is built on top of the WSO2 Carbon platform. It utilizes many features made available by the Carbon platform. A data service can be summarized into a XML descriptor file written in compliance with Data Services Descriptor Language (DSDL). DSDL is a XML based language defined by WSO2 to write data services.

A custom deployer, written extending the Apache Axis2 deployer framework is responsible for reading this data service descriptor and creating a data service. XML processing capabilities offered by Apache AXIOM is used for generating XML responses

on the fly. Some of the third party open-source applications used by the Data Services Server include Apache DBCP for managing connection pools for Relational Databases, Google Spreadsheet Data API for reading Google Spreadsheets, OpenCSV for CSV file support and Apache POI for MS-Excel support.

### Governance Registry Architecture

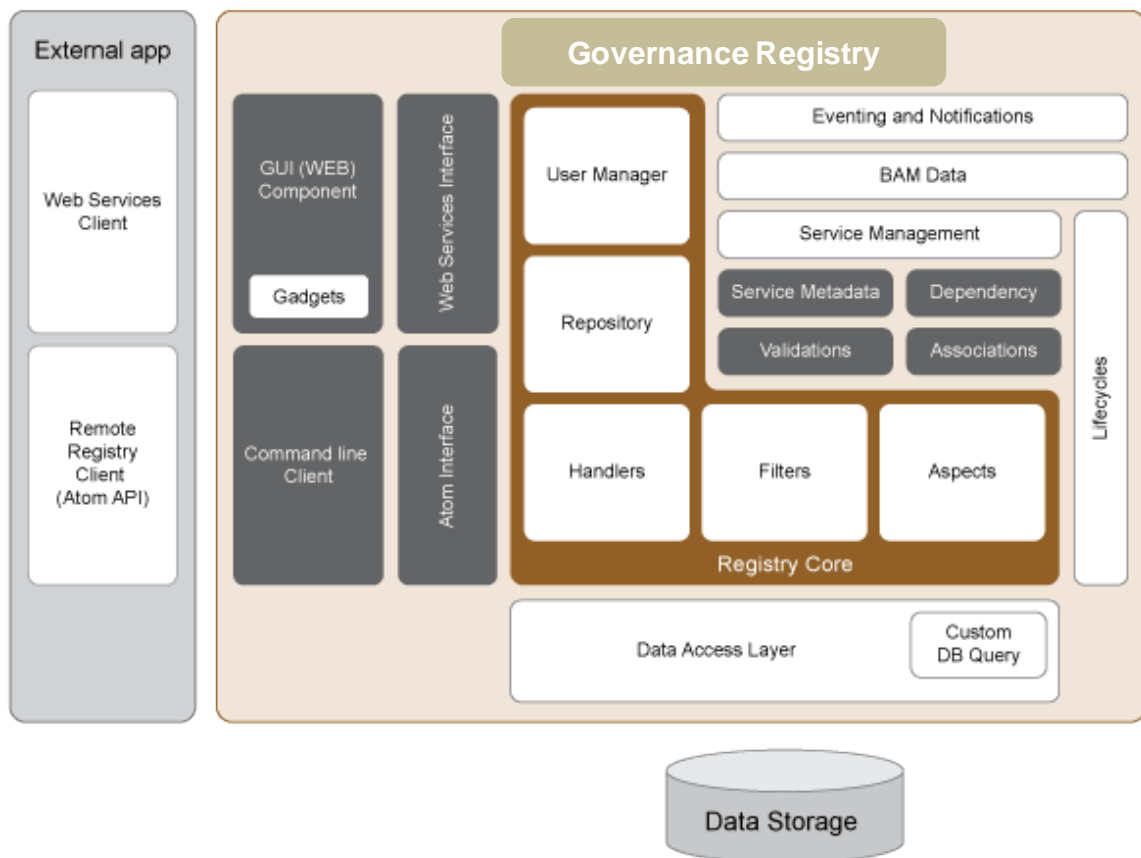


Figure 47: Governance Registry Architecture

The Governance Registry is a standalone layer. It can be deployed as a Java EE application on top of common application servers. By default, the content is stored in a built-in H2 database. The functionality of the Governance Registry can be extended using

its handler and filter concepts. Registry operations are accessible via the Remote Registry API.

## Web Services Application Server Architecture

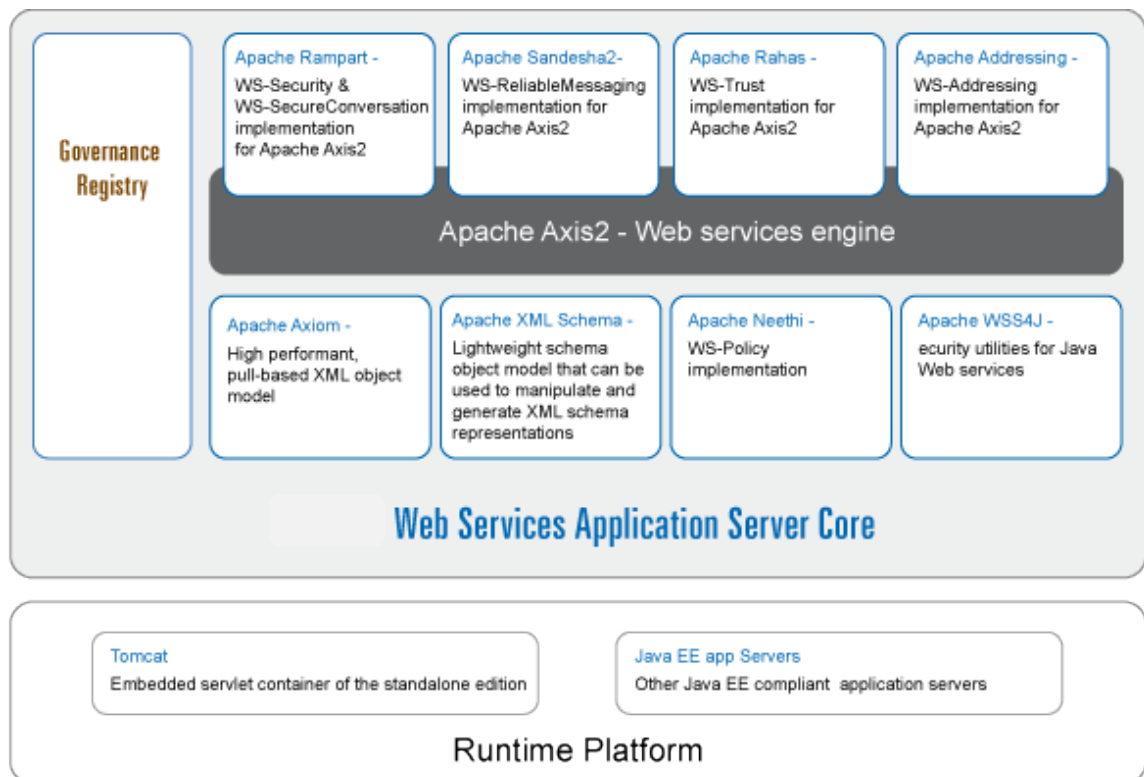


Figure 48: Web Services Application Server Architecture

The Web Services Application Server (WSAS) integrates a number of common Apache Web services components. At the core of WSAS is the Apache Axis2/Java Web services engine. Apache Axis2 has an extensible messaging engine architecture, so that other Quality of Service (QoS) modules can be plugged into the environment.

## Business Process Server Architecture

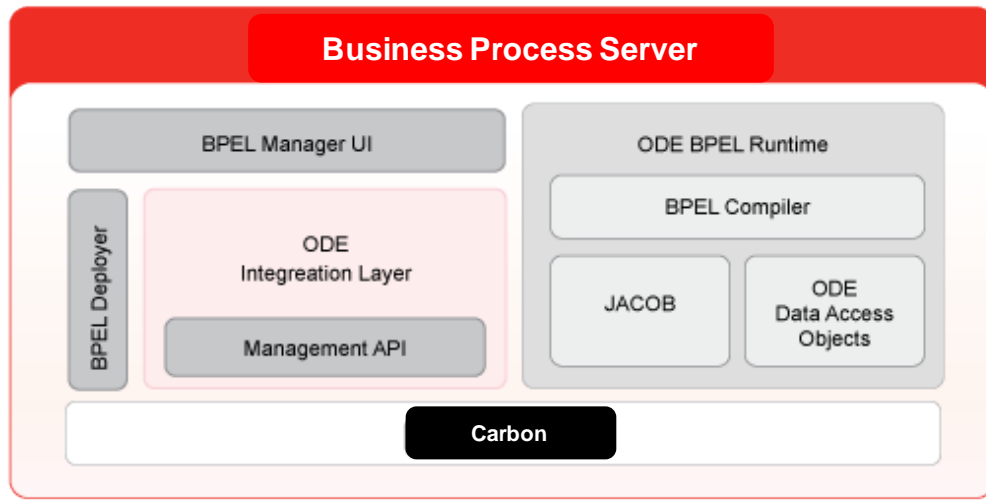


Figure 49: Business Process Server Architecture

Powered by Apache ODE, the Business Process Server (BPS) manages and monitors business processes written following WS-BPEL. ODE's Java Concurrent Object framework provides an application level concurrency mechanism and transparent mechanism for interrupting execution and persisting execution state while Data Access Object provides the persistence facilities required for the BPS.

### Security Server Architecture



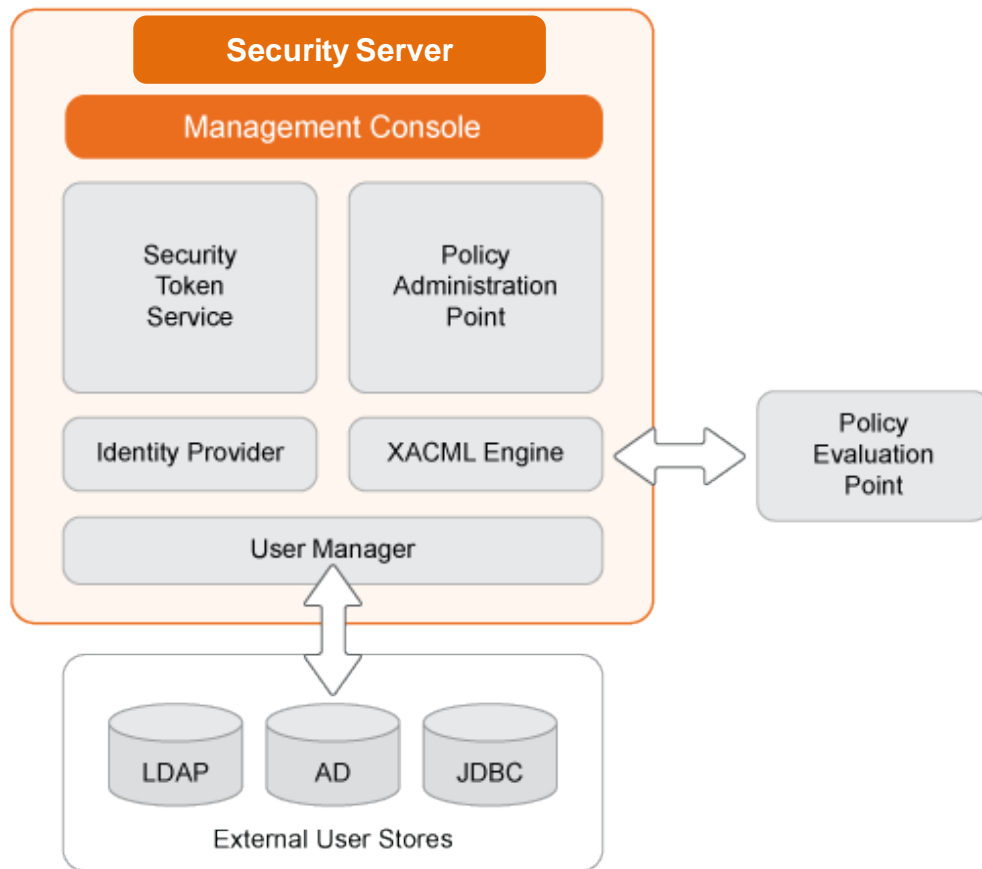


Figure 50: Security Server Architecture

The Security Server extends the popular Apache Web Services Projects such as Apache Rampart, Apache WSS4J and Apache XMLSecurity as well as WSO2 Carbon. It is released under the Apache License v2.0. The user manager component of the Security Server decouples user attribute handling from the upper layers which further facilitates claim based access to the underlying user store.

## Enterprise Service Bus Architecture

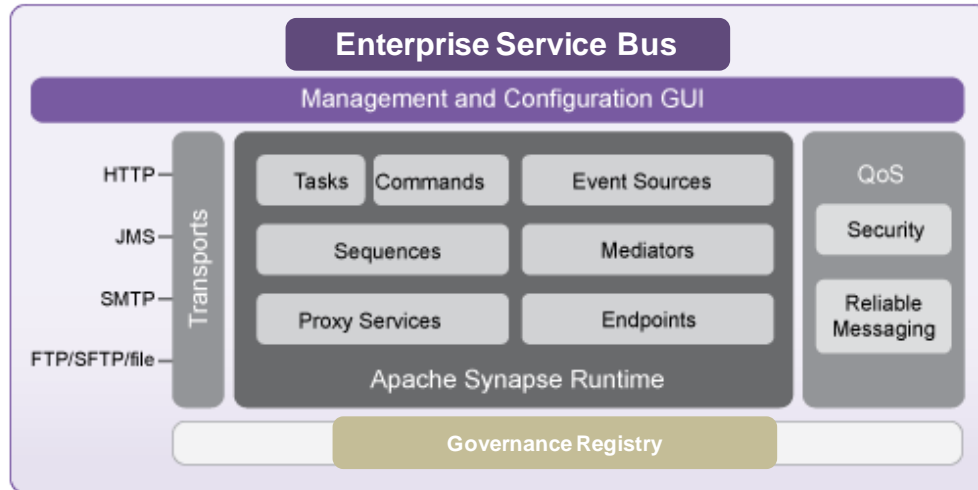


Figure 51: Enterprise Service Bus Architecture

Powered by the Apache SynapseESB project, the ESB is optimized for the highest low latency, while remaining lightweight. A combination of non-blocking IO and a streaming XML parsing design means that the ESB can scale to common environments.

## LIST OF REFERENCES

- AgilePath Corporation. "Addressing SOA Governance Challenges: Introducing AgilePath's SOA Governance Reference Model v. 1.0". AgilePath White Paper; 2006. Available online: [www.agilepath.com](http://www.agilepath.com).
- Allen, P., Service Orientation, winning strategies and best practices, Cambridge, UK: Cambridge University Press. ISBN 0521843367.
- Asit, D. Johnson, R., Arsanjani, A., "Information as a Service: Modeling and Realization", International Workshop on Systems Development in SOA Environments, 2007, SDSOA '07: ICSE Workshops 2007, 20-26 May 2007, page(s): 2 - 2
- AT&T, "AT&T Wireless Self-Destructs", CIO Magazine, April 15, 2004.
- Basili, V. R.; Caldiera, G.; Rombach, H. D.: The Goal Question Metric Paradigm. In: Marchiniak J. J. (ed.): Encyclopedia of Software Engineering. New York 2002, pp. 578-583.
- BEA. (2007). Right from the Start: SOA Life Cycle Governance. Whitepaper, March 2007.
- Bichier, M., Lin, K. J., "Service-oriented computing", Computer, March 2006 Volume: 39, Issue: 3, page(s): 99 – 101
- Bieberstein et al. (2007). "Executing SOA: A Practical Guide for the Service-Oriented Architect". (Paperback), IBM Press books, 978-0132353758.
- Bieberstein, N.; Sanjay Bose, Marc Fiammante, Keith Jones, Rawn Shah (2006), "Service-Oriented Architecture Compass - Business Value, Planning and Enterprise Roadmap", Upper Saddle River: Pearson. ISBN 0-13-187002-5.
- Black, C., Sprinkle, R., "Joint BC & Simulation Systems Initialization Process", Paper 06F-SIW-114, 2006 Fall Simulation Interoperability Workshop, 2006
- Blalock, J.: "Army Initialization Capability Strategic Approach White Paper", Chief Information Officer/G-6, August 26, 2005.
- Böhmman, T.; Schermann, M.; Krcmar, H.: Reference Model Evaluation: Towards an Application-Oriented Approach. Forthcoming in: Fettke, P.; Loos, P. (eds.): Reference Modeling for Business Systems Analysis. Hershey et al. 2007.

- Carlton, B., Scrudder, R., Black, C., Hopkins, M.: "Initialization of C4I Systems and Simulation Federations Today and in the Future", Paper 04FSIW-089, 2004 Fall Simulation Interoperability Workshop, 2004.
- Carleton, B. "Transition of ACSIS Simulation Initialization Capability to the Army Objective Initialization Capability (OIC) Program." Technical Note. Applied Research Laboratories. The University of Texas in Austin, 2006.
- Choi, S.W., Her, J.S., Kim, S.D. "QoS Metrics for Evaluating Services from the Perspective of Service Providers." IEEE International Conference on e-Business Engineering. 2008.
- Department of Defense Directive, "DoD Modeling and Simulation Management". Number 5000.59, August 8, 2007.
- Department of Defense Chief Information Officer, "DoD Net Centric Services Strategy: Evolving the DoD Net-Centric Environment to an Enterprise Service Oriented Architecture". October 2006.
- Department of Defense Army Memorandum, "Army Data Initialization Implementation Plan". May 21, 2007.
- Department of Defense Joint Requirement Oversight Council Memorandum, "Data Strategy Implementation for Warfighter Domain Systems". JROCM 152-05. July 18, 2005.
- DMSO, "Unit Order of Battle Data Access Tool User Manual", 1999, <<http://www.uxxi.org/docs/c4i-repository/uobdat3.pdf>>
- DODSBIR, "Common Databases", 2007, <[http://www.dodsbir.net/sitis/view\\_pdf.asp?id=MTPS%20Roadmap%20CDB%20and%20GIDM%20Sections.doc](http://www.dodsbir.net/sitis/view_pdf.asp?id=MTPS%20Roadmap%20CDB%20and%20GIDM%20Sections.doc)>.
- Dorn, J. Grun, C. Werthner, H. Zapletal, M., "A Survey of B2B Methodologies and Technologies: From Business Models towards Deployment Artifacts", 40th Annual Hawaii International Conference on System Sciences, 2007, HICSS 2007, Jan. 2007, page(s): 143a - 143a
- Erl, Thomas, SOA Principles and Service Design, Upper Saddle River: Prentice Hall PTR. ISBN 0-13-234482-3. 2007.
- Furness, Z. "Applying Lessons Learned from Systems Engineering of Distributed Simulation Systems to Service-Oriented Architectures", NDIA M&S Conference. 18 April 2006.

- Gartner, Inc. "SOA Governance", 2007,  
<[http://www.gartner.com/whitepapers/SOA\\_Governance.pdf](http://www.gartner.com/whitepapers/SOA_Governance.pdf)>
- Gustavsson, P. M., Å. Björk, C. Brax, and P. Planstedt, "Towards Service oriented Simualtions," presented at FallSIW 04, Orlando, Florida, 2004.
- Hewlett Packard. "The Eight Most Important Best Practices in SOA Governance". HP SOA Systinet White Paper; 2008. Available online: [www.hp.com](http://www.hp.com).
- Hieb, M. R., and Blalock, J., "Data Alignment between Army C4I Databases and Army Simulations." 1999 Spring Simulation Interoperability Workshop. Orlando, Florida.
- Henninger, A., DaCosta, B., Lucas, T. "OneSAF Data Evolution: A Multi-Strategy Approach", I/ITSEC 2003. Orlando, Florida.
- Hofmeister, C., Nord, R., Soni, D. Applied Software Architecture. Addison-Wesley, 2000.
- Howerton, J.T., "Service-Oriented Architecture and Web 2.0", IT Professional, May-June 2007 Volume: 9, Issue: 3, page(s): 62 - 64
- HQDA G3/5/7 Memorandum, subject: Command and Control Information Exchange Data Model, 28 September 2005.
- HQDA G3/5/7 Memorandum, subject: C2IEDM Migration to JC3IEDM, 06 June 2006.
- Huhns, M.N. Singh, M.P., "Service-oriented computing: key concepts and principles", IEEE Internet Computing, Jan-Feb 2005 Volume: 9, Issue: 1, page(s): 75 - 81
- Hyacinth S. Nwana. "Software Agents: An Overview", Knowledge Engineering Review, 11(3):1-40, September 1996, Cambridge University Press.
- IBM, "Effective SOA Governance", Governing Service-Oriented Architecture, 2006.
- IBM, "Virtualization and SOA Synergies Propel Competitive Advantage", <<http://www-03.ibm.com/systems/virtualization/view/101006.html>>. Retrieved on 27 January 2008.
- IBM. (2006). Implementing Technology to Support SOA Governance and Management. Technical Report, December 2006
- InfoWorld. (2006). "Factors Inhibiting SOA Adoption". Research Report: SOA, July 2006.

- JFCOM, "Command seeking market research from industry and academia on integrated, Web-based capability", 2007,  
<<http://www.jfcom.mil/newslink/storyarchive/2007/pa041907.html>>
- JFCOM, "Joint Integrated Database Preparation System (JIDPS)", 2007,  
<[http://www.jfcom.mil/about/fact\\_jidps.htm](http://www.jfcom.mil/about/fact_jidps.htm)>
- Jones, S. Capgemini, "Toward an acceptable definition of service", IEEE Software, May-June 2005, Volume: 22, Issue: 3, page(s): 87 - 93
- Josuttis, M. N. (2007). "SOA In Practice: The Art of Distributed System Design." O'Reilly Media, Inc., Sebastopol, CA.
- Kihn, E.A., Zhizhin, M., Siquig, R., and Redmon, R., "The Environmental Scenario Generator (ESG): A Distributed Environmental Data Archive Analysis Tool", *Data Science Journal*, Volume 3, Pgs. 10-28, 4 February, 2004.
- Kontogiannis, K., Grace A. Lewis, Dennis B. Smith, Marin Litoiu, Hausi Müller, Stefan Schuster and Eleni Stroulia, "The Landscape of Service-Oriented Systems: A Research Perspective", International Workshop on "Systems Development in SOA Environments: SDSOA" May 20-26th, 2007, ICSE Workshops 2007.
- Krafzig, D., Karl Banke, Dirk Slama (2004), Enterprise SOA Service Oriented Architecture Best Practices, Upper Saddle River: Prentice Hall PTR. ISBN 0-13-146575-9.
- Lanman, J.T., Proctor, M.D. (2009). "Governance of Data Initialization for Service Oriented Architecture-based Military Simulation and Command & Control Federations". *Journal of Defense Modeling and Simulation: Application, Methodology, Technology*, Vol. 6, No. 1, 5-16 (2009), DOI: 10.1177/1548512909344525.
- Lewis, G.A., Morris, E., Simanta, S., Wrage, L., "Common Misconceptions about Service-Oriented Architecture", Sixth International IEEE Conference on Commercial-off-the-Shelf (COTS)-Based Software Systems, 2007, ICCBSS '07, Feb. 26 2007-March 2 2007, page(s): 123 - 130
- Lian Jie Zhang, Haifei Li, Lam, H., "Services computing: grid applications for today", IT Professional, Jul-Aug 2004 Volume: 6, Issue: 4, page(s): 5 - 7
- Linthicum, D. (2003), Next Generation Application Integration: From Simple Information to Web Services, New York: Addison-Wesley Professional. ISBN 978-0201844566.

- LogicLibrary. "Logidex: Development – Time Governance". SOA Software; 2008.  
Available online: [www.logiclibrary.com](http://www.logiclibrary.com).
- Ma, K.J., "Web services: what's real and what's not?" IT Professional, March-April 2005  
Volume: 7 , Issue: 2, page(s): 14 - 21
- Mann, Andi, "Virtualization 101", Enterprise Management Associates (EMA),  
<[http://www.emausa.com/ema\\_lead.php?ls=virtwpws0806&bs=virtwp0806](http://www.emausa.com/ema_lead.php?ls=virtwpws0806&bs=virtwp0806)>.  
Retrieved on 27 January 2008.
- Margaria, T., Steffen, B., "Service Engineering: Linking Business and IT", Computer,  
October 2006, Volume: 39 , Issue: 10, page(s): 45 - 55
- Margolis, B. (2007), SOA for the Business Developer: Concepts, BPEL, and SCA, Mc  
Press. ISBN 978-158347065.
- Marks, E.; Michael Bell (2006), Service Oriented Architecture: A Planning and  
Implementation Guide for Business and Technology, Hoboken: John Wiley &  
Sons, ISBN 978-0471768944.
- Menasce, D. A. (2002). QoS Issues in Web Services. IEEE Journal on Internet  
Computing, 6(6).
- Menascé, D.A., Ruan, H., Gomaa, H. (2007). QoS management in service-oriented  
architectures. International Journal on Performance Evaluation, v.64 n.7-8,  
p.646-663, August 2007.
- Metz, G.S., "IT architecture for homeland security", IEEE Conference on Military  
Communications, 2005. MILCOM 2005, 17-20 Oct. 2005, page(s): 292 - 298  
Vol. 1
- Microsoft Corporation. (2008). SOA Governance and the Microsoft Ecosystem.  
Technical Whitepaper, July 2008.
- Mills, J., "A Joint Perspective on SOA Implementation", SOA Technical  
Symposium. Suffolk, VA, July 2007.
- Military Scenario Definition Language (MSDL) Study Group Final Report [for], SISO-  
REF-015-2006, 10 January 2006.
- Misic, V. B.; Zhao, J. L.: Evaluating the Quality of Reference Models. In: Leander, A. H.  
F.; Liddle, S. W.; Storey, V. C. (eds.): Conceptual Modeling – ER 2000: 19<sup>th</sup>  
International Conference on Conceptual Modeling. Lecture Notes in Computer  
Science. Berlin et al. 2000. pp. 484-498.

- OASIS. (2006), "OASIS Reference Model for Service Oriented Architecture v.1.0". Organization for the Advancement of Structured Information Standards, page 29, August 2006.
- OpenGroup. (2009). A Standard Framework for SOA Governace. Technical Report, October 2009.
- Oracle. (2008), "Right from the Start: SOA Life Cycle Governance". Oracle White Paper; June 2008. Available online: [www.oracle.com/technologies/soa/docs/soa-governancerightstart-whitepaper.pdf](http://www.oracle.com/technologies/soa/docs/soa-governancerightstart-whitepaper.pdf).
- Papazoglou, M.P., Van den Heuvel, W.J. Tilburg, "Web services management: a survey", IEEE Internet Computing, Nov.-Dec. 2005 Volume: 9, Issue: 6, page(s): 58 - 64
- Papazoglou, M.P., Willem-Jan Heuvel, "Service oriented architectures: approaches, technologies and research issues", The VLDB Journal - The International Journal on Very Large Data Bases Volume 16, Issue 3 (July 2007), Pages: 389 - 415
- Paul, R.A., "Tomorrow's needs - yesterday's technology: DoD's architectural dilemma & plan for resolution", Ninth IEEE International Symposium on High-Assurance Systems Engineering, 2005. HASE 2005, 12-14 Oct. 2005, page(s): 9 - 12
- Paul, R.A., "DoD towards software services", 10th IEEE International Workshop on Object-Oriented Real-Time Dependable Systems, 2005 (WORDS 2005) 2-4 Feb. 2005, page(s): 3 - 6
- Perrey, R. Lycett, M., "Service-oriented architecture", Proceedings of Symposium on Applications and the Internet Workshops, 2003, 27-31 Jan. 2003, page(s): 116 - 119
- Pulier, Eric, Hugh Taylor, Understanding Enterprise SOA, Greenwich: Manning Publications. ISBN 1-932394-59-1. 2005
- Roy, Satadru, "SOA Infrastructure: Mediation and Orchestration", November 2006, <<http://searchsoa.techtarget.com>>
- Schroth, C. Janner, T. St. Gallen, "Web 2.0 and SOA: Converging Concepts Enabling the Internet of Services", IT Professional, May-June 2007 Volume: 9, Issue: 3, page(s): 36 - 41
- Schroth, C. Christ, O., "Brave New Web: Emerging Design Principles and



- Technologies as Enablers of a Global SOA”, . IEEE International Conference on Services Computing, 2007, SCC 2007, 9-13 July 2007, page(s): 597 - 604
- Schroth, C., “Web 2.0 versus SOA: Converging Concepts Enabling Seamless Cross-Organizational Collaboration”, The 9th IEEE International Conference on E-Commerce Technology and the 4th IEEE International Conference on Enterprise Computing, E Commerce, and E-Services, 2007. CEC/EEE 2007, 23-26 July 2007, page(s): 47 - 54
- Shane, R.: “ABCS & FBCB2 Database Inconsistencies: Design vs. Implementation White Paper”, 27 March 2002.
- Shane, R., Allitt, E., “Army C41 & Simulations Initialization System (ACSIS): Using Distributed Database Technologies to Propagate Initialization Data”, *Local to Global Data Interoperability - Challenges and Technologies 2005*, Pgs. 155-159. IEEE, June 2005.
- Sprinkle, R., Brown, R.: “Capability-Based Development of Future C4ISR Systems”, Paper 04SSIW-156, 2004 Spring Simulation Interoperability Workshop, 2004.
- Sprinkle, R., Kelso, T., Whitehead, S.: “Battle Command and Simulation Data Model Decision”, Paper 05F-SIW-117, 2005 Fall Simulation Interoperability Workshop, 2005.
- Software Engineering Standards Committee of the IEEE Computer Society, IEEE 1471-2000 – IEEE Recommended Practice for Architectural Description of Software-Intensive Systems, The Institute of Electrical and Electronics Engineering, Inc, 3 Park Avenue, New York, NY 10016-5997, 21 September 2000.
- Sun Microsystems. (2006). SOA Governance Solution: Accelerating SOA. Whitepaper, January, 2006.
- Szych, B., “Joint Synthetic Battlespace Overview”, U.S. Air Force. September 2003, <[www.amso.army.mil/resources/smart/conf/2003/Focus%20Sessions-03/fs-szych.ppt](http://www.amso.army.mil/resources/smart/conf/2003/Focus%20Sessions-03/fs-szych.ppt)>.
- Tolk, A., “Operational Modeling and Simulation Services in Military Service Oriented Architectures”, White Paper: 6<sup>th</sup> Annual ONR Conference, September 8-9, 2004, Quantico, VA.
- Tolk, A., David Perme, Saikou Diallo, Cynthia Pandolfo, Bryan Tedesco, Huong Tran, “Joint Event Data Initialization Services (JEDIS) - Implementing a Service Oriented Architecture for Initialization”, Spring Simulation Interoperability Workshop, Simulation Interoperability Standards Organization, IEEE CS Press, 2007.

- Tolk, A. 2003. Common data administration, data management, and data alignment as a necessary requirement for coupling C4ISR systems and M&S. *Information and Security* 12(2): 164–174.
- Tolk, A. 2003a. Beyond technical interoperability – introducing a reference model for measures of merit for coalition interoperability. In *Proceedings of the Command and Control Research and Technology Symposium (CCRTS)*, CCRP Press.
- Tolk, A. 2004. XML mediation services utilizing model based data management. In *Proceedings of the 2004 Winter Simulation Conference*, ed. R. G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters, 1476-1484. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.
- Tolk, A. and R. D. Aaron. 2007. A common data engineering architecture. White Paper. Army Test and Evaluation Command, Washington, DC.
- Tolk, A. and S. Y. Diallo. 2005. Model based data engineering for Web services. *IEEE Internet Computing* 9(4): 65-70.
- Tolk, A., S. Y. Diallo, C. D. Turnitsa, and L. S. Winters. 2006. Composable M&S Web services for netcentric applications. *Journal for Defense Modeling and Simulation* 3(1): 27-44.
- Tolk, A. and S. Y. Diallo. (2008). “Model Based Data Engineering for Web Services.” Chapter 6 in Nayak et al. (Eds.): *Evolution of the Web in Artificial Intelligent Environments*, SCI 130, pp. 137-161. Springer, 2008.
- Tolk, A., J. Mark Pullen. (2005). Using Web Services and Data Mediation/Storage Services to Enable Command and Control to Simulation Interoperability. *Proceedings of the 2005 Ninth IEEE International Symposium on Distributed Simulation and Real-Time Applications*. IEEE Computer Society.
- TRADOC Program Integration Office Battle Command (TPIO-BC), Draft Concept of Operations (CONOPS) for Initialization and Data Loading, 21 June 2006.
- Tsai, W.T. Malek, M. Yinong Chen Bastani, F., “Perspectives on Service-Oriented Computing and Service-Oriented System Engineering”, Second IEEE International Workshop on Service-Oriented System Engineering, 2006, SOSE '06., Oct. 2006, page(s): 3 - 10
- Tsai, W.T., “Service-oriented system engineering: a new paradigm”, *Service-Oriented System Engineering*, 2005. SOSE 2005. IEEE International Workshop. 20-21 Oct. 2005, page(s): 3 - 6

- U.S. Army PEO STRI. "JLCCTC Product Description", 2007,  
<<http://www.peostri.army.mil/PRODUCTS/JLCCTC/>>.
- U.S. Army PEO STRI. "APM SECore Description", 2007,  
<[http://www.peostri.army.mil/PM-CATT/APM\\_SECore.jsp](http://www.peostri.army.mil/PM-CATT/APM_SECore.jsp)>.
- U.S. Army TPIO Battle Command. "CONOPS for Initialization and Data Loading."  
Technical Report. SIMCI Program, 2006.
- U.S. NAVAIR. "Navy Aviation Simulation Master Plan", 2007,  
<<http://www.virtc.com/dts.jsp>>.
- Van den Berg, M., Norbert Bieberstein, Erik van Ommeren (2007), SOA for Profit, A  
Manager's Guide to Success with Service Oriented Architecture, Sogeti & IBM.  
ISBN 978-90-75414-14-1.
- Vietmeyer, R. "DoD Goes SOA: The Road Toward Net-Centric Operations", The SOA  
Forum. DISA, March 2005.
- Volker, H.. "Data Standardization as the Basis for an Service Oriented Architecture",  
Proceedings of the IEEE Services Computing Workshops (SCW'06), IEEE  
Computer Society. 2006.
- WebMethods. (2006). SOA Governance: Enabling Sustainable Success with SOA.  
Whitepaper, October 2006.
- Wittman, R.. "Common Data In and Across Complex System of Systems", MITRE  
Tech Review Presentation. January 09, 2006.
- WS02 Open Source SOA Company. "Govern". WS02 Products to Govern Services;  
2009. Available online: <http://wso2.com/products/govern/>.
- ZapThink. "SOA Governance and the Butterfly Effect". ZapThink White Paper; 2006.  
Available online: <http://www.zapthink.com/report.html?id=ZAPFLASH-2006124>.
- Zeng, H., Son, T.C. "Semantic Web Services". Intelligent Systems, (IEEE) 16: 46–53;  
March 2001.