

**System of Systems  
Systems Engineering Guide:  
Considerations for Systems Engineering  
in a System of Systems Environment**



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**For System of Systems Pilot Project**

**Version .9**

**Director, Systems and Software Engineering  
Deputy Under Secretary of Defense (Acquisition and Technology)  
Office of the Under Secretary of Defense  
(Acquisition, Technology and Logistics)**

# For SoS Pilot Project

## Contents

Abbreviations and Acronyms .....	3
Preface .....	5
1. Introduction.....	7
1.1. Purpose and Scope.....	7
1.2. Definition of Terms.....	12
1.2.1. System of Systems .....	12
1.2.2. System of Systems Engineering .....	13
1.2.3. Governance, Interoperability, and Asset Management .....	15
2. System of Systems Environment.....	17
2.1. SoS SE Environment Perspectives .....	17
2.1.1. Community Involvement: Stakeholders, Governance .....	17
2.1.2. Operational Environment: Mission Environment, Operational Focus .....	18
2.1.3. Implementation: Acquisition/Test and Validation, Engineering.....	19
2.1.4. Summary of Differences .....	21
2.2. Profiling the SoS SE for the Example Cases.....	22
3. Technical Management Processes and Technical Processes .....	28
3.1. Technical Management Processes .....	29
3.2. Technical Processes .....	42
4. Example System of Systems Engineering Programs.....	55
4.1. New Development Programs .....	55
4.2. Development of New Capability by Integrating Current Systems .....	61
4.3. Mixed System Maturity Levels.....	64
4.4. Sustaining Capabilities/Engineering .....	69
4.5. Business Systems.....	71
5. Summary .....	73
Appendix: Glossary and Literature Survey .....	76
References .....	87

## For SoS Pilot Project

### Figures

Figure 1-1 Profiler of Systems Continuum and Challenges for Systems Engineering (R. Stevens, MITRE Corp, 2006) .....	9
Figure 1-2 Scope of This Guide in Context of Spectrum of SoS .....	10
Figure 1-3 Relationship between SoS SE and SE of Constituent Systems .....	15
Figure 3-1 Technical Management Processes and Technical Processes Defined in the DAG, Chapter 4.....	28
Figure 4-1 The FCS Concept Diagram .....	56
Figure 4-2 System of Systems Engineering Approach for FCS .....	57
Figure 4-3 Integrated Deepwater System .....	59
Figure 4-4 The ABCS Concept Diagram .....	62
Figure 4-5 NIFC-CA Concept Diagram .....	65
Figure 4-6 SIAP P2P SoS Implementation (Jacobs 2004) .....	68
Figure 4-7 Context Diagram for the CARTS System.....	72

### Tables

Table 1-1 Net-Centric Information Environment: Attributes.....	14
Table 2-1 Comparison of Characteristics of Systems and SoS.....	21
Table 2-2 Examples of System of Systems Programs .....	23
Table 2-3 SoS SE Environment Profile for the Example Cases .....	25

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### Abbreviations and Acronyms

ABCS	Army Battlefield Command System
ACAT	Acquisition Category
ACDB	Army Common Data Base
ACTD	Advanced Concept Technology Demonstrations
ATD	Advanced Technology Demonstrations
BCS	Battle Control System
BCT	Battlefield Communications Terminal
BOS	Battlefield Operating System
BTP	Build-to-Packages
C4ISR	Command Control Communications Computers Intelligence Surveillance and Reconnaissance
CARTS	Commissary Advanced Resale Transaction System
CCIR	Command Critical Information Requirements
CI	Configuration Item
CJCSM	Chairman of the Joint Chiefs of Staff Manual
CM	Configuration Management
COTS	Commercial Off The Shelf
DECA	Defense Commissary Agency
EOA	Evaluation Of Alternatives
EVM	Earned Value Measurement
FBCB2	Field Battle Command Brigade and Below
FCS	Future Combat Systems
GCCS-A	Global Command and Control System-Army
IABM	Integrated Architecture Behavior Model
ICD	Interface control documents
IDE	Integrated development environment
IDS	Integrated Deepwater System
IEEE	Institute of Electrical and Electronic Engineers
IMS	Integrated Master Schedule
INCOSE	International Council on Systems Engineering
IPT	Integrated Product Team
IT	Information Technology
JCIDS	Joint Capabilities Integration and Development System
JEFX	Joint Expeditionary Force Experiments
JMD	Joint Missile Defense
JSSEO	Joint SIAP Systems Engineering Organization
JTE	Joint Test and Evaluation
JWARS	Joint Warfare System
MCS	Maneuver Control System
MDA™	Model Driven Architecture
MOSA	Modular Open Systems Architecture

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NIFC-CA	Naval Integrated Fire Control Counter Air
OOA	Object Oriented Architecture
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
PEO	Program Executive Officer
PIM	Platform Independent Model
PM	Program Manager
PSM	Platform Specific Models
SA	Structure Analysis
SBCT	Stryker Brigade Combat Team
SE	Systems Engineering and Systems Engineers
SE&I	System Engineering & Integration Office
SEP	Systems Engineering Plan
SIAP	Single Integrated Battle Picture
SIL	System/Simulation / Software integration Laboratory
SLEP	Service Life Extension Program
SME	Subject Matter Expert
SOA	Service oriented Architecture
SOE	System Operational Effectiveness
SoS	System of Systems
SoSCOE	System-of-Systems Common Operating Environment
TBMCS	Theater Battle Management Core System
TDP	Technical Data Packages
TPM	Technical Performance Measurement
TRL	Technical Readiness Level
TTP	Tactics, Techniques, Procedures

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### Preface

In order to best support the warfighter in military operations and to provide efficient support and readiness in peacetime, the Department of Defense (DoD) continually seeks to develop new capabilities and achieves a growing number of these capabilities through a system of systems (SoS) approach. As defined in the DoD *Defense Acquisition Guidebook*, an SoS is “a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities” (Section 4.2.6). DoD has developed SoS in the past but has recently increased its emphasis on such systems to respond to new threats, to address coalition and joint warfare, and to incorporate rapidly changing communications and information technology. SoS complexity has increased dramatically, leading to new challenges in architecture, networks, hardware and software engineering, and human systems integration. All these challenges must be addressed as several new SoS efforts are already under way.

Although there are a number of differing viewpoints on SoS, this first version of the SoS Engineering (SoSE) guide focuses on the class of SoS with a defined user need, resources designated to address the need, and a clearly defined entity with the responsibility to address this need. The guide is intended to capture aspects of consensus and associated lessons learned on this class of SoS and represents an initial step toward addressing SE considerations for DoD SoS. This guide is written mainly from the perspective of the DoD SoS sponsor(s), Program Manager (PM) and Chief Engineer. It incorporates principles of the *Defense Acquisition Guidebook* Chapter 4 (Systems Engineering) and expands on that chapter to address key considerations for SE for this class of SoS. The authors recognize that this guide only begins to address the broad set of SoS SE challenges. Subsequent versions of the guide will increase in scope and coverage to further investigate and capture specific knowledge on SoS, which have increasingly ill-defined boundaries, requirements, and program ownership.

SE practices and approaches historically have been described with a single system rather than an SoS in mind. This guide defines the SoS environment for the initial class of SoS, analyzes examples of current SoS programs within this class, and presents findings and recommendations from that analysis to enhance the reader’s understanding of SoS SE.

## For SoS Pilot Project

Specifically, the guide addresses the 16 DoD Technical Management Processes and Technical Processes, along with other processes necessary for the delivery of SoS capabilities.

This guide assumes an understanding of SE and is intended as a reference only and not as a comprehensive SE manual. This guide applies SE principles, as defined in the Defense Acquisition Guidebook and leading SE standards, to the SoS environment.

The Office of the Secretary of Defense (OSD) is first putting this .9 version of the guide through a pilot project prior to its final publication. In this project OSD will ask a few SoSs to apply the guide to their systems engineering processes and provide feedback on the guide's utility. The pilot project serves as a functional checkout of the guide before general distribution.

The OSD will update the guide periodically to expand the scope of SoS classes considered, to reflect advances in SoS SE application, and to capture additional best practices and lessons learned.

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## 1. Introduction

### 1.1. Purpose and Scope

This guide is intended to be an initial step toward addressing systems engineering (SE) considerations for system of systems (SoS) within the Department of Defense (DoD).

With the changes to both the requirements development (CJCSI 3170) and acquisition (DoD 5000) processes over the past 5 years, there has been increased emphasis on addressing “user capability needs” versus simply developing new systems. There has been a change in the way requirements are identified and prioritized, and a recognition that decisions in these areas need to be made in a broader capability or portfolio context. Concept development and capabilities-based analyses have become the basis for definition of user needs, and acquisition roadmaps and more recently capability portfolios are being explored as a mechanism for investment decisions. With the adoption of a net-centric approach to information management, there is a recognition that systems always operate in a broader context. Most important, changing threat situations increase the need for flexibility and adaptability in the way DoD configures and applies systems to respond to changing situations. The notion of “systems of systems” and “enterprises” is becoming a critical perspective in thinking about systems.

As DoD develops guidance for program managers and systems engineers, it faces a number of specific challenging considerations. Although these considerations are not unique to DoD, they frame the context for understanding why SoS and enterprise issues are critical for defense:

- **Scale**
  - The sheer size of the defense enterprise makes a single integrated architecture infeasible, and thus architecting SoS and their relationship to this enterprise is challenging and often inconsistent.
- **Ownership/management**
  - The individual systems that compose SoS are owned by the military services or agencies, introducing constraints on management and SE for the SoS.



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- **Legacy**
  - Given defense budget projections, current systems will remain in the defense inventory for the long term and must be factored into any approach to SoS.
- **Changing operations**
  - Changing threats and concepts mean that new (ad hoc) SoS configurations will be needed to address changing, unpredictable operational demands.
- **Criticality of Software**
  - SoS are typically designed with a focus on integration across systems through cooperative or distributed software.
- **Role of network**
  - Conceptually, DoD SoS are already /will be increasingly network/internet/web based; budget and legacy issues could translate to uneven implementation

The SE community (including members of industry, academia, government, and commercial program offices) is paying increasing attention to issues of SoS, complex systems, and enterprise systems. Community members have divergent views about the nature of these types of systems and their implications for SE, and SoS can take a variety of forms. There is considerable research under way on the nature of complex adaptive systems and the role of emergent behavior in these systems, and a wide range of perspectives on the role of SE in these environments.

Figure 1-1 displays one view of the complexity of the current environment of system characteristics. This “profiler” suggests there is a continuum of environments for systems, beginning in the center with situations in which a system is well defined, user needs are clear and relatively stable, and technologies needed to implement the system are understood and mature. As represented in the figure, the center is the area best addressed by traditional SE practices and has been the focus of DoD SE policy. As one moves out from the center, definition and clarity decrease, complexity and uncertainty increase, and challenges grow.

























































































































































































