Tailoring USAF Systems Engineering for the Life Cycle: One Shape, Multiple Dimensions

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What’s Up

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- What is USAF SE?

- Key USAF SE Interactions

- SE “V” Diagram and Applications
  - Basic
  - Complex System, Subsystem, and Platform
  - SoS / Architecture
  - Life Cycle
  - Incremental Acquisition

- Next?
What is USAF SE?

Air Force Center for Systems Engineering (CSE) definition

Systems Engineering is the discipline encompassing the entire set of scientific, technical, and managerial processes needed to conceive, evolve, verify, deploy, and support an integrated system-of-systems (SoS) capability to meet user needs across the life cycle.
What is USAF SE?

Implications for Practitioners

- **Breadth**
  - Knowledge across technical disciplines and engineering functions is required to ensure rigorous technical processes are applied
  - Must apply engineering capabilities, tools, and techniques to anticipate issues with requirements, acquisition, test, and sustainment of AF capabilities
  - Must ensure application of SE principles to families of systems (FoS), systems of systems (SoS), air platforms, weapons, command and control (C2), and space systems, as well as subsystems and components

- **Expertise (Depth)**
  - Capability, domain, or enterprise level engineering expertise
  - Requires focused technical management on joint/coalition capabilities; goes beyond standard interface engineering

- **Life Cycle Perspective**
  - Must apply systematic processes, technical processes, and measurements to promote mission assurance throughout the life cycle
  - Must not limit scope/range with respect to requirements development, science and technology (S&T), product/system development, or sustainment
  - Operational safety, suitability, and effectiveness (OSS&E) characteristics must be identified, maintained, assessed, and analyzed

*Integrity - Service - Excellence*
What is USAF SE?
A Management / Leadership Vision

Interfacing / integrating engineering and technical “threads” with architecture development, capabilities planning, science and technology, developmental (products / systems) engineering, and sustainment

INTEGRATED POLICY AND COLLABORATION REQUIRED ACROSS “ENGINEERING PROCESS THREADS”
Interfacing / integrating engineering and technical “threads” with architecture development, capabilities planning, science and technology, developmental (products / systems) engineering, and sustainment

INTEGRATED POLICY AND COLLABORATION REQUIRED ACROSS “ENGINEERING PROCESS THREADS”
Key USAF SE Interactions

**SE Policy**
- SAF/AQX
- SAF/AQR
- AFMC/EN
- NSSO
- AFSPC/DR

**Academia**
- USAFA
- CSE
- LAI EdNET

**Education & Training**
- AIA
- AF/ILM

**Industry**
- INCOSE
- GEIA
- SAF/ACE

**Other Govt**
- ASD (NII)
- NDIA
- SAF/USA
- OUSD (AT&L)
- ASA (ALT)
- OSJTF
- ASN (RDA) / CHENG

**AF Acquisition Support**
- AFRL
- AFSAA
- SAF/XCX
- Product Center ENs / ACEs
- Logistics Center ENs / ACEs
- Test Center ENs / ACEs

**Key USAF SE Interactions**
- Product Center ENs / ACEs
- Logistics Center ENs / ACEs
- Test Center ENs / ACEs
SE “V” Diagram Applied to a Complex System
SE “V” Diagram Applied to a Major Vehicle System

SE “V” Diagram:

- **ALLOCATED REQUIREMENTS**
- **MAJOR SUBSYSTEM DESIGN**
- **COMPONENT DESIGN**
- **COMPONENT FABRICATION**
- **COMPONENT INTEGRATION / VERIFICATION**
- **SUBSYSTEM INTEGRATION / VERIFICATION**
- **SYSTEM INTEGRATION / VERIFICATION**
- **SYSTEM VERIFICATION**
- **MAJOR SUBSYSTEM DESIGN**
- **COMPONENT DESIGN**
- **COMPONENT FABRICATION**
- **COMPONENT INTEGRATION / VERIFICATION**
- **SUBSYSTEM INTEGRATION / VERIFICATION**
- **SYSTEM INTEGRATION / VERIFICATION**
- **SYSTEM VERIFICATION**

Subsystems:
- Low Pressure Spool
- Combustion Section
- High Pressure Spool
- Lubrication
- Controls

**Fractions**
SE “V” Diagram Applied to a Weapon System (Platform)

Figure adapted from NDIA Modeling & Simulation Committee Final Report to OUSD (AT&L), Mar 2004
SE “V” Diagram with SoS and Architecture Perspective

Figure adapted from NDIA Modeling & Simulation Committee Final Report to OUSD (AT&L), Mar 2004
Robust weapon systems, & all their subsystems, function properly; weapon systems can safely operate and deliver capability in the battlespace.

**SV “Success Criteria”**

- Robust weapon systems, & all their subsystems, function properly;
- Weapon systems can safely operate and deliver capability in the battlespace.

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**Integrity - Service - Excellence**
Robust weapon systems, & all their subsystems, function properly; weapon systems can safely operate and deliver capability in the battlespace.

All players in the battlespace can interoperate; capability delivery is essentially “plug-and-fight”.
SoS Awareness

- Ideally, individual systems and platforms are:
  - Managed by competent program managers
  - Well understood by the major system integrators who have successfully developed, tested, fielded, and supported them
  - Regulated by robust acquisition processes

- Systems-of-systems, and their corresponding mission capabilities, are often:
  - Literally “assembled on-the-fly” by operational commanders in response to emerging threats or requirements
  - Of relatively short lifecycle when compared to traditional systems that remain “intact” for extended periods of time
  - Not managed or funded under a single or consolidated authority

Adapted from Open Systems Joint Task Force
SoS Issues

- SoS Engineering is not a defined / applied discipline
  - Long history of reasonable success, GIVEN pre-determined needs (explicit requirements) for interconnection / interoperability
  - Dynamic operational environments demand spontaneous interconnection / interoperability

- Lots of policy (even more guidance) on what should be done (e.g., net-ready KPP) … but few specifics on how to achieve
  - “On the network” doesn’t necessarily mean “Interoperable in real time”
  - “Best Commercial Practices” don’t always mesh well with unique military issues
    - Security
    - Commander’s Intent
    - Resource prioritization and rapid reallocation
    - Unintended consequences

DAU Publications Distribution Center
Govt performs most SE tasks

Efforts largely conducted at study / project level

Somewhat ad hoc use of tools and disciplines

Key objectives:
- Evaluate architecture
- Evaluate support capabilities

SE-related steps during Concept Refinement

I n t e g r i t y  -  S e r v i c e  -  E x c e l l e n c e
Some SE responsibilities transition from Govt to contractor

Efforts largely conducted as discrete projects or small programs

Key process areas employ selected tools & disciplines

Key objectives:
- Reduce technical risk
- Determine appropriate technologies to integrate

SE-related steps during Technology Development
“Traditional” SE applications: Govt manages contractors who perform most SE tasks
Efforts generally conducted at program / capability level
All process areas employ key tools and disciplines

Key objectives:
- Finalize all levels of requirements
- Develop product & system details
- Produce hardware and software
- Integrate and verify product / system

SE-related steps during System Development & Demonstration
Some SE responsibilities transition from contractor back to Govt.
Efforts largely conducted as discrete projects or small programs.
Key process areas employ selected tools and disciplines.

Key objectives:
- Verify that desired operational capability can be produced, delivered, and employed.
- Ensure that the system continues to mission needs.

SE-related steps during Production & Deployment.

**Integrity - Service - Excellence**
Govt performs most SE tasks
Efforts largely conducted at study / project level
Somewhat ad hoc use of tools and disciplines

Key objectives:
- Ensure the system continues to meet performance requirements in the integrated architecture
- Cost-effective sustainment
Some SE responsibilities transition to (TD) and from (P&D) contractor:

- Project level
- Key process areas employ selected tools and disciplines

Reduce technical risk
Determine appropriate technologies to integrate
Provides operational capability
Meets mission needs
Govt performs most SE tasks
- Study / project level
- Use of tools and disciplines: somewhat ad hoc in CR; not SE-specific in O&S
  ➠ Evaluate architecture
  ➠ Evaluate support capabilities
  ➠ Meets performance requirements in the integrated architecture
  ➠ Cost-effective sustainment

Some SE responsibilities transition to (TD) and from (P&D) contractor
- Project level
- Key process areas employ selected tools and disciplines
  ➠ Reduce technical risk
  ➠ Determine appropriate technologies to integrate
  ➠ Provides operational capability
  ➠ Meets mission needs
Govt performs most SE tasks
- Study / project level
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Evaluate architecture
Evaluate support capabilities
Meets performance requirements in the integrated architecture
Cost-effective sustainment

Some SE responsibilities transition to (TD) and from (P&D) contractor
- Project level
- Key process areas employ selected tools and disciplines

Reduce technical risk
Determine appropriate technologies to integrate
Provides operational capability
Meets mission needs

"Traditional" SE applications:
Govt manages contractors who perform most SE tasks
- Program / capability level
- All processes areas employ key tools and disciplines

System Development and Demonstration Phase

Option 1 - Base Case
- Traditional
- Performance
- Evaluation
- Definition & Evaluation
- Architecture
- Support Capabilities
- Performance

Option 2 - Traditional
- Architecture
- Support Capabilities
- Performance
- Evaluation
- Definition & Evaluation
- Architecture
- Support Capabilities
- Performance

Option 3 - Traditional
- Architecture
- Support Capabilities
- Performance
- Evaluation
- Definition & Evaluation
- Architecture
- Support Capabilities
- Performance

Option 4 - Traditional
- Architecture
- Support Capabilities
- Performance
- Evaluation
- Definition & Evaluation
- Architecture
- Support Capabilities
- Performance

Option 5 - Traditional
- Architecture
- Support Capabilities
- Performance
- Evaluation
- Definition & Evaluation
- Architecture
- Support Capabilities
- Performance
Traditional SE applications:
- Govt manages contractors who perform most SE tasks

Program / capability level:
- All process areas employ key tools and disciplines
- Govt performs most SE tasks

Evaluate architecture
- Meets performance requirements in the integrated architecture
- Cost-effective sustainment

Evaluate support capabilities

Some SE responsibilities transition (TD) and from (P&D) contractor

Technology Development Phase:
- Project level
- Key process areas employ selected tools and disciplines
- Reduce technical risk
- Determine appropriate technologies to integrate
- Provides operational capability
- Meets mission needs

System Integration / Verification

System Development & Demonstration Phase:
- Study / project level
- Use of tools and disciplines: somewhat ad hoc in CR; not SE-specific in O&S

Operations & Support Phase:
- Evaluate architecture
- Evaluate support capabilities
- Meets performance requirements in the integrated architecture
- Cost-effective sustainment
Govt performs most SE tasks

- Study / project level
- Use of tools and disciplines: somewhat ad hoc in CR; not SE-specific in O&S
  - Evaluate architecture
  - Evaluate support capabilities
  - Meets performance requirements in the integrated architecture
  - Cost-effective sustainment

Shortfalls depicted as capability-based requirements for next increment (or new acquisition)

Some SE responsibilities transition (TD) and from (P&D) contractor

- Project level
- Key process areas employ selected tools and disciplines
  - Reduce technical risk
  - Determine appropriate technologies to integrate
  - Provides operational capability
  - Meets mission needs

Shortfalls depicted as capability-based requirements for next increment (or new acquisition)
Linear View of Incremental System / Program Life Cycle

Increment 1

Increment 2

Increment 3

... Increment n ...

Integrity - Service - Excellence