Competencies Required for Successful Acquisition of Large, Highly Complex Systems of Systems

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Agenda

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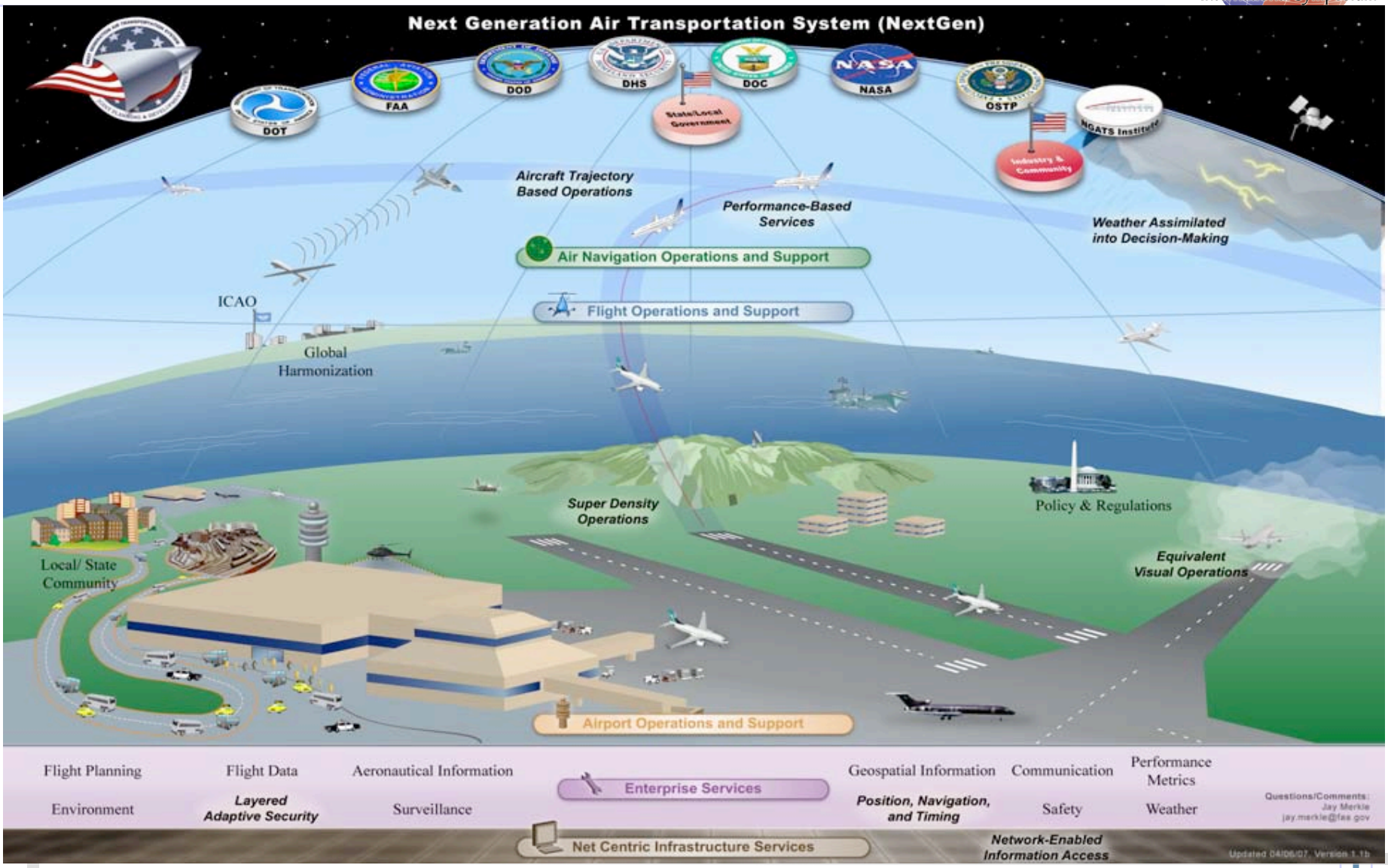
- Definitions
- Sources
- Model
- Key Factors
- Critical Competencies
- Recommendations



Approach

- **Step 1:** Develop a generic competency model for the three disciplines of interest (SE, SI, and SwE) that is applicable beyond the FAA.
- **Step 2:** Identify key SE, SI, and SwE activities and artifacts that are critical to the success of a large and complex SoS such as NextGen.
- **Step 3:** Identify the SE, SI, and SwE competencies from the generic model that are most critical to the key activities and artifacts identified in Step 2.

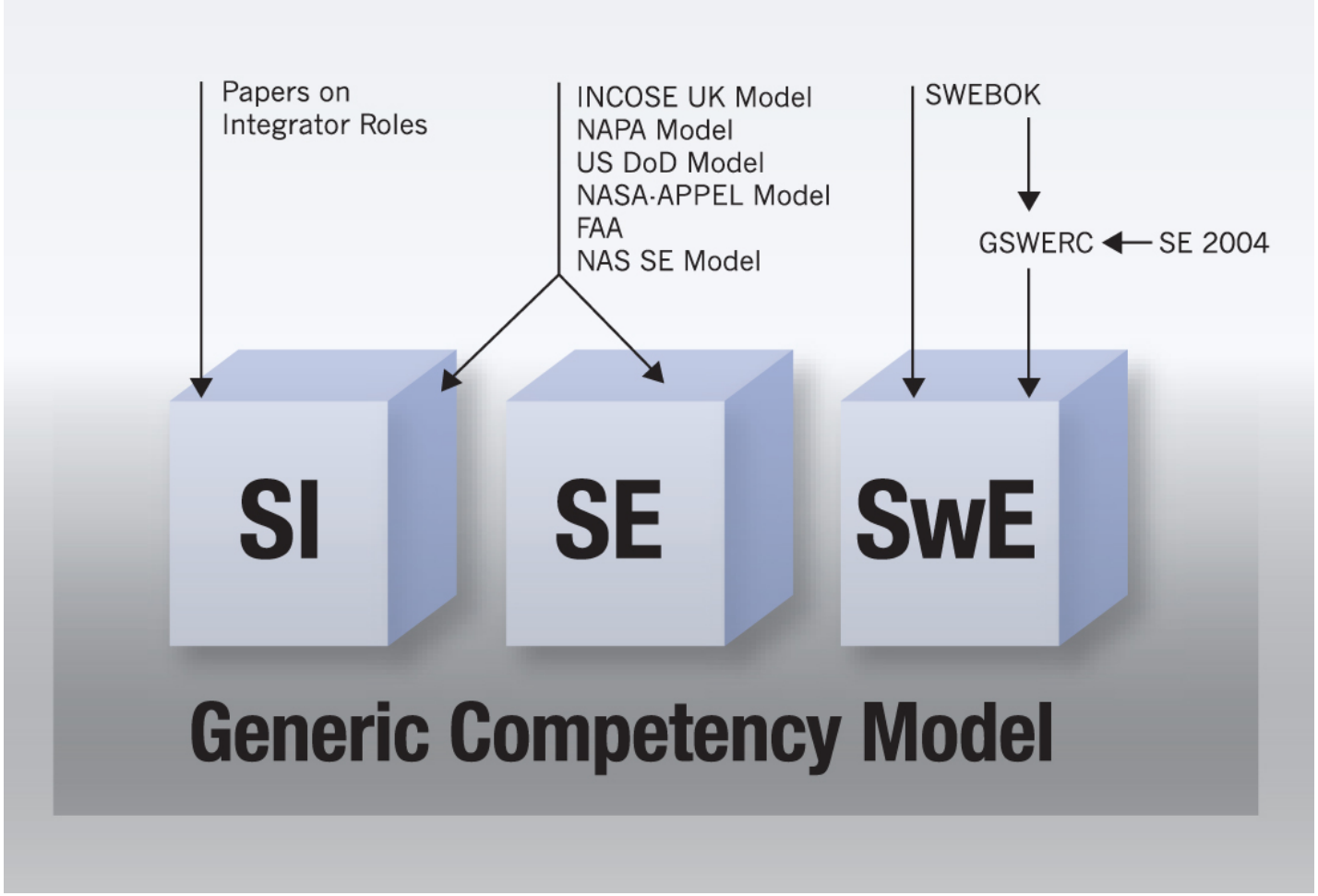
Competency Definition

- Individual

  ***Competency**: An observable, measurable set of skills, knowledge, abilities, behaviors, and other characteristics an individual needs to successfully perform work roles or occupational functions. Competencies are typically required at different levels of proficiency depending on the specific work role or occupational function. Competencies can help ensure individual and team performance aligns with the organization's mission and strategic direction.* (US Office of Personnel Management)

- Organizational – Individual competency is aided or hindered by:
  - Management understanding and support,
  - Organizational structure,
  - Governance practices,
  - Culture,
  - Facilities, tools, and processes

Competency Model - Sources



COMPETENCE AREA – Holistic Lifecycle View: *Determining and Managing Stakeholder Requirements*

Description:

To analyse the stakeholder needs and expectations to establish and manage the requirements for a system.

Why it matters:

The requirements of a system describe the problem to be solved (its purpose, how it performs, how it is to be used, maintained and disposed of and what theexpectations of the stakeholders are). Managing the requirements throughout the lifecycle is critical for implementing a successful system.

EFFECTIVE INDICATORS OF KNOWLEDGE AND EXPERIENCE

AWARENESS	SUPERVISED PRACTITIONER	PRACTITIONER	EXPERT
Understands the need for good quality requirements. Able to identify major stakeholders. Understands the importance of managing requirements throughout the lifecycle. Understands the need to manage both technical and nontechnical requirements.	Able to identify all the stakeholders and their sphere of influence. Can support the elicitation of requirements from stakeholders. Understands the characteristics of good quality requirements. Understands methods used in requirements gathering. Understands the need for traceability between the design and the requirements. Understands the relationship between requirements and acceptance. Understands the relationship between requirements and modelling. Able to establish acceptance criteria for simple requirements	Has successfully elicited stakeholder requirements. Has written good quality requirements. Able to produce a system requirements specification. Able to write the requirements management plan including categorisations and structures. Able to define a process to manage the requirements and ensure its effective implementation. Can demonstrate effective assessment of the impact of change. Able to resolve and negotiate requirement conflicts in order to establish a complete and consistent requirement set. Able to establish acceptance criteria for complex requirements. Identifies areas of uncertainty and risk when determining requirements. Able to challenge appropriateness of requirements in a rational way. Able to validate the requirements. Able to guide supervised practitioner.	Approves requirements management plans. Reviews system requirements specification. Acknowledged as an authority in the elicitation and management of requirements. Conducts the sensitive requirements negotiations on major programmes. Advises on compliance. Able to advise on the validity of requirements. Has coached new practitioners in this field. Has championed the introduction of novel techniques and ideas in this field which produced measurable improvements Has contributed to best practice.

II. Holistic Lifecycle View

The skills associated with the systems lifecycle from need identification and, requirements determination through to operation and ultimately disposal.

Competency	Knowledge/Skills Required	Behavioral Indicators
Stakeholder Management	• Knowledge of the need for good quality requirements • Skill to be able to identify major stakeholders • Knowledge of the importance of managing requirements throughout the lifecycle • Knowledge of the need to manage both technical and non-technical requirements	• Successfully elicits stakeholder requirements • Develops good quality requirements • Produces a system requirements specification • Writes the requirements management plan including categorizations and structures • Defines a process to manage the requirements and ensure its effective implementation • Effectively assesses the impact of change • Works with smart buyers from industry to manage contracts • Resolves and negotiates requirement conflicts in order to establish a complete and consistent requirement set • Establishes acceptance criteria for complex requirements • Identifies areas of uncertainty and risk when determining requirements • Challenges appropriateness of requirements in a rational way • Validates the requirements

DOD

Unit of Competence	Competency	Elements	Knowledge Items
#1 Analytical	Requirements Development	Apply the Requirements Development process to translate inputs from relevant stakeholders into technical requirements.	Knowledge of requirements management tools

FAA Draft

Knowledge Areas	Engineer	Senior Engineer	System Engineer	Senior System Engineer	Chief Systems Engineer
Operational and Systems Requirements • What are requirements? • Differences between operational and systems requirements • Requirements Development Process • Tools for Gathering Requirements • Characteristics of a good requirement • Examples of good and bad requirements	Familiarity with Requirements Development Process	A recognized expert in requirements development; sought out as a consultant performance	A recognized expert in requirements development; sought out as a consultant performance	A recognized expert in requirements development; special insight into potential improvements in its performance.	A recognized expert in requirements development; special insight into potential improvements in its performance.

Source Information Structures

- INCOSE UK –
  - Description, why it matters
  - Indicators: aware, supervised, **practitioner**, expert
- NAPA – Knowledge/Skills, **Behavior indicator**
- Stevens space – competency, criticality, **appendix**
- DoD – **elements, knowledge**
- FAA – **Knowledge areas**, 5 levels
- SSCI – **Knowledge elements**
- DoD SOS – 7 core elements, **relation to core**
- Integration papers – **points**

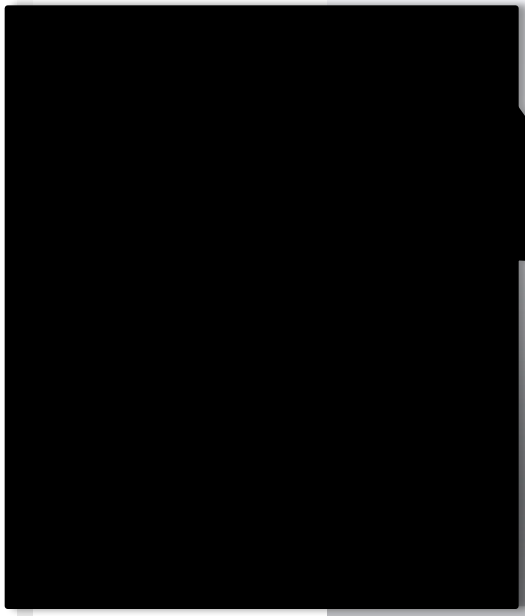
Source Contributions to SE/SI

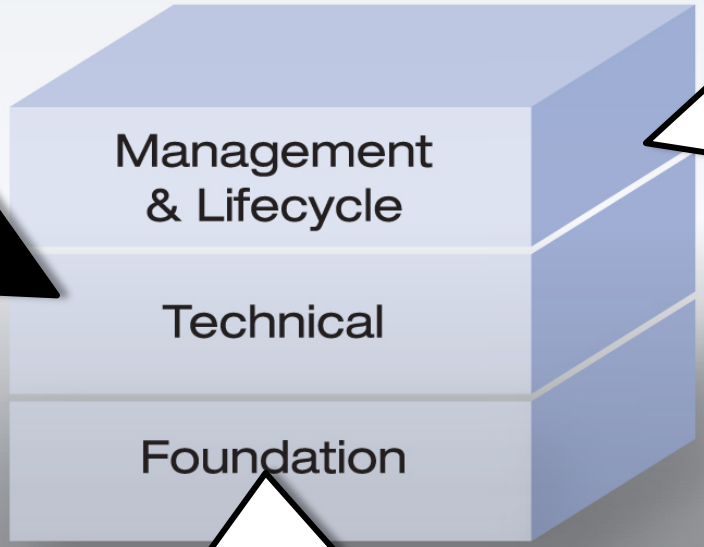
- INCOSE UK – systems thinking, technical, mgt
- NAPA – safety, assurance, CE/ME/EE/CS
- Stevens space – needs, ops environ, org environ
- DoD – cost, communications, analytic skills
- FAA – level detail
- SSCI – “exeption thinking”
- DoD SOS – SOS implications
- Integration papers – systems integrator view

Competency Model - Options

- Option 1 - Three separate models
  - Three separate models for SE, SI and SwE
- Option 2 – Two models
  - One model for SE highlighting what's special for SI
  - One model for SwE
- Option 3 – One unified model
  - One full model including all competencies for SE, SI and SwE
  - Columns for SE, SI and SwE to indicate what's relevant for each
  - **Emphasize the commonality among the disciplines**

Competency Groups





- Professional Competencies
- Systems Thinking
- SE Concepts and Fundamentals
- Mathematical Skills
- Technical Skills

- SE Process
- SE Management
- Safety Engineering and Assurance System Attributes
- Organizational Environments

Foundation Competencies

Second Level	Third Level
Personal Competencies	Motivation, Self-Regulation, Social / Interpersonal Skills, Empathy, Self-Awareness
Professional Competencies	Communications – Oral, Communications – Written, Computer and Internet Usage Skills, Social, legal, and historical issues, Codes of ethics and professional conduct, Decision Making, Problem Solving, Influence and Negotiation
Math, Science and Engineering Fundamentals	Algebra and Trigonometry, Discrete Structures, Propositional and Predicate Logic, Probability and Statistics, Fundamental Calculus, Computing Fundamentals
Systems Thinking	Systems Concept, "System of Systems" Capability Issues, Enterprise and Technology Environment, Strategic Thinking, Divergent Thinking, Holistic Lifecycle View, Handling Uncertainty, Pattern Recognition, Recent developments and future trends
Domain Knowledge	Organization and Mission, Operations, Technical Disciplines

Systems Thinking Third Level Descriptions

Third Level	Description of Third Level
Systems Concept	Sees the collection of elements and their interaction rather than only individual parts
"System of Systems" Capability Issues	Works effectively with external components that are both essential to overall performance and not directly owned
Enterprise and Technology Environment	Considers the constraints and opportunities of the enterprise and the available technology
Strategic Thinking	Has a vision of where the program is going in the long term
Divergent Thinking	Expands the problem and solution space beyond what is given
Holistic Lifecycle View	Recognizes the interaction of the lifecycle phases and activities
Handling Uncertainty	Effectively works in an environment where key factors have not been resolved
Pattern Recognition	Applies core principles learned in dissimilar situations

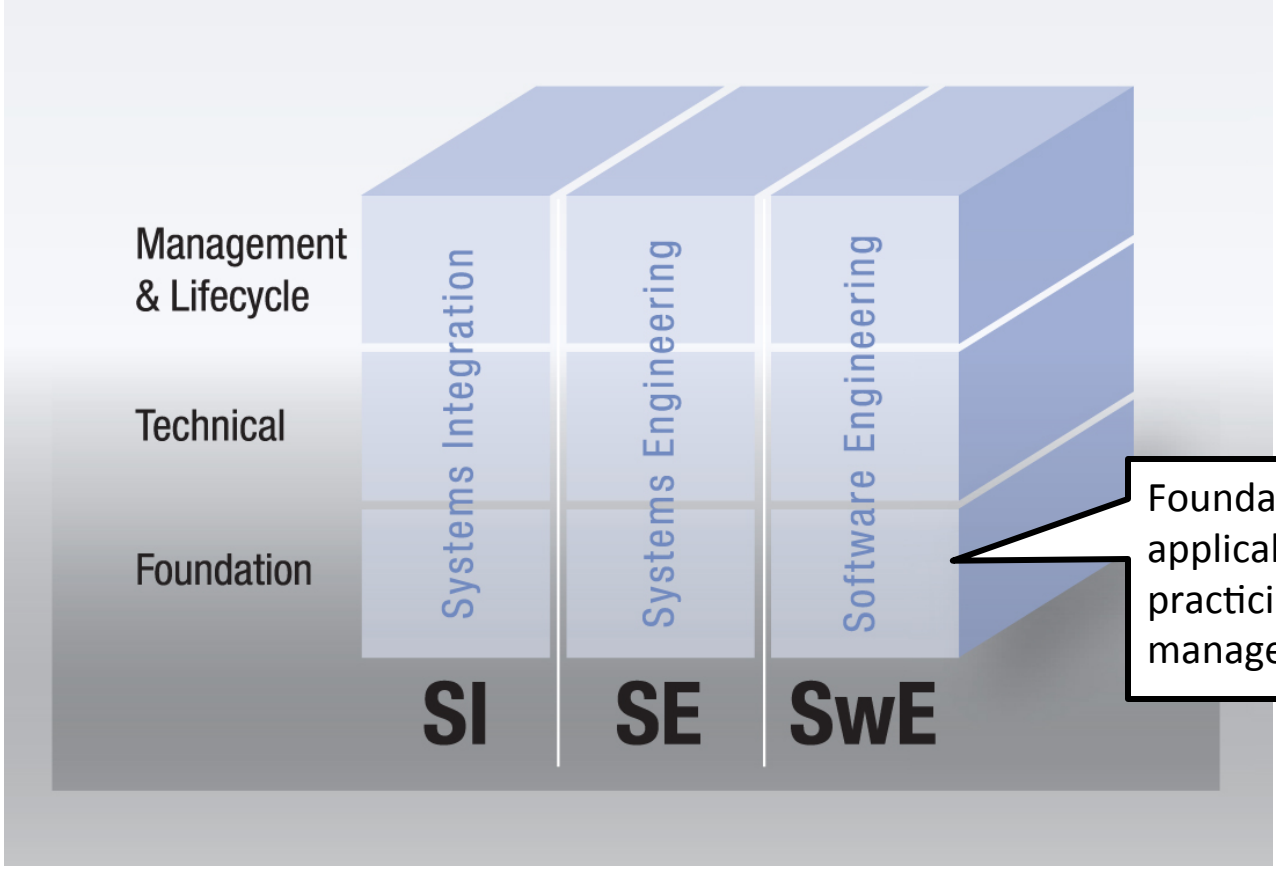
Technical Competencies

Second Level	Third Level
Requirements	Requirements Elicitation, Requirements Analysis, Requirements Validation, Requirements Management
Analysis	Functional Analysis, Modeling and Simulation, Trade Studies
Architecting and Design	Concept Generation, Concept Selection, Architecting Principles, Solution Selection, Human Factors Engineering, COTS
Implementation	Implementation Strategies, Fabrication/Construction
Integration	Standards and Interfaces, Methods of Integration, Transition to Operation
Verification	Types of Testing, Test Plan, Quality Control, System Verification
Validation	Identification of Validation Needs, Methods of Validation
Maintenance	Types of Maintenance, Maintenance Procedures, Logistics
Disposal	System Retirement and Disposal, Environmental Issues
Attributes	Quality, Safety, Assurance, Security, Agility, Robustness

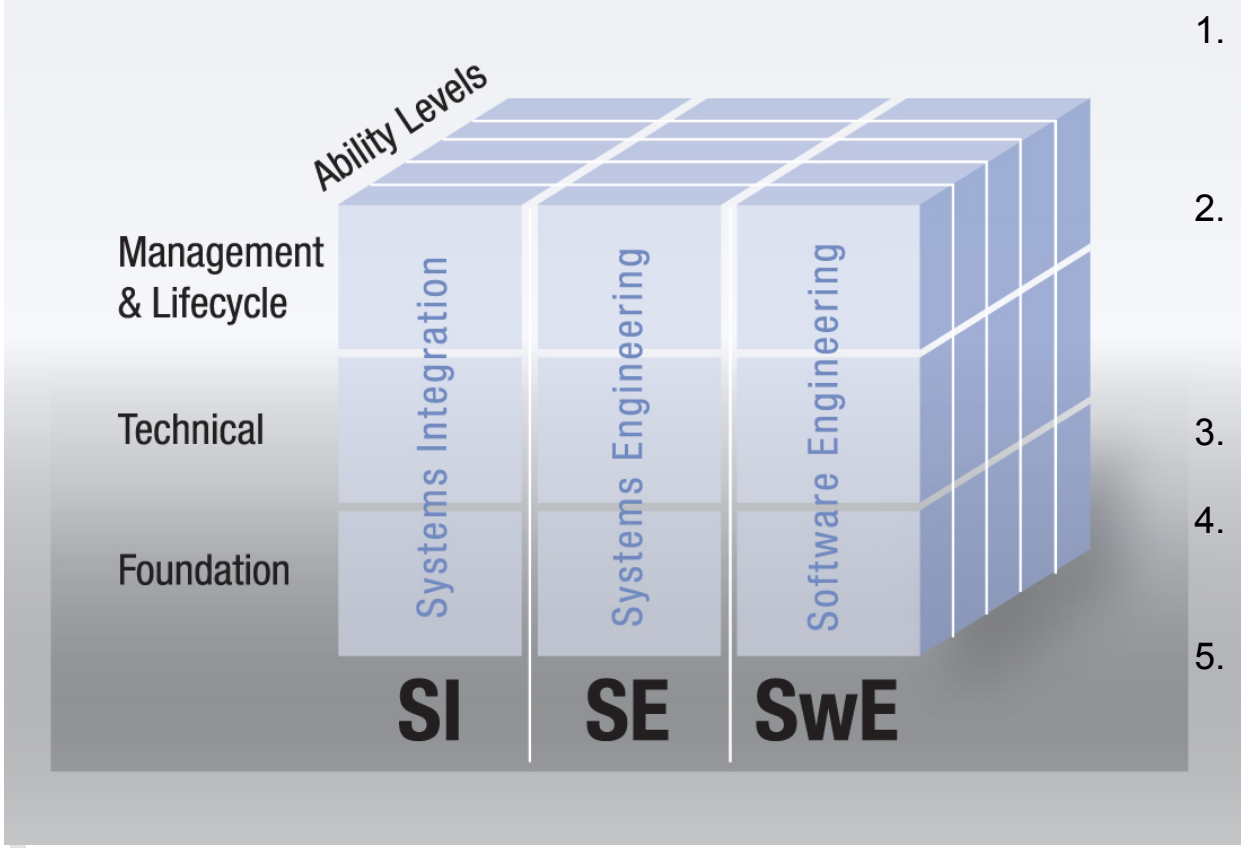
Management Competencies

Second Level	Third Level
Process	Life cycle Process Definition, Standards, Acquisition, Process Tailoring, Tools
Management	Enterprise Integration, Integration of Fields of Specialization, Planning, Monitoring and Controlling, Engineering Economics & Cost Analysis, Technical Reviews, Configuration Management, Technical Data Management, Human Capital Management, Risk Management
Governance	Organizational Structures, Manage Contractors/Sub-Contractors, Manage External Agencies, International Relations, Policy, Governance Principles, Business Value

Competency and Roles



Competency and Ability



1. Cognizant – Aware of but not able to perform, can appreciate and work with those who perform
2. Entry practitioner – Can perform basic tasks with supervision, can understand and work with those who perform
3. Practitioner – Can perform basic tasks without supervision
4. Lead – Can select from multiple techniques to perform task and can supervise others
5. Expert – Fully capable in multiple techniques, can review and supervise, adds to field

Role Relation to System Level

Role / System Level	System Integrator	System Engineer	Software Engineer
System of Systems	Integrate development of component systems; ensure that the SoS meets the users' needs	Perform SE tasks at SoS level as part of overall SI	Provide software (SW) input to SoS architecture; act as SW stakeholder supporting SoS analysis and decisions
Systems (Classic)	Part of SE role	Perform classic SE tasks and roles	Provide SW input to SoS architecture; act as SW stakeholder, supporting system analysis and decisions
Software	Complexity	Part of SwE role	Develop SW

Key Factors in Complex SoSs

- CONOPS
- Enterprise architecture
- Governance structure
- Culture

These drive the critical competencies

11 Critical Competencies

- Systems Thinking
- Communications, both oral and written
- Negotiation and Influence
- Integration
- Governance
- Planning
- Architecture and Design
- Functional Analysis
- Verification
- Validation
- Security (specifically, cyber security)

3 Key Organizational Factors

- Management—managers at all levels who make decisions that can help or hinder the effectiveness of the systems engineer, systems integrator, or software engineer should be aware of the need for these disciplines and their value to the organization
- Governance Structure—the set of decision rights, methods, and artifacts to select, value, oversee, provision, and control development projects so that they deliver business value
- Culture—the attitudes and behaviors of the organization

General Recommendations

1. Learn the current proficiency of the workforce in the 11 critical competencies through surveys, interviews, and other data collection methods
2. Define the current needs in more detail and project the change in both number in the workforce and their level proficiency
3. Educate, train, mentor, and otherwise grow the competency of the current workforce and adjust hiring practices
4. Analyze the organizational environment to ensure that
    1. its governance structure is effectively supporting the full use of capabilities,
    2. management understands the value and content of the SI, SE, and SwE efforts,
    3. the culture supports a true systems approach to both implementation and subsequent operations.
5. Measure and monitor progress

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