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The Department of the Navy Systems Engineering Career Competency Model

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The Department of the Navy Systems Engineering Career Competency Model

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Abstract

The Naval Postgraduate School is developing a competency model for the profession of systems engineering. There is currently no professional engineering occupational code (08XX) for systems engineers, so there is no verified competency model source to use for human resource functions related to systems engineers. The key objective of the systems engineering competency career model (SECCM) project is to develop a verified systems engineering career competency model that can be used as a foundation for establishing construct validity for SE related human resources actions. To ensure the SE competency model will be able to be used this way, the SECCM project is having OPM use a standard approach to verify the occupational analysis in compliance with the *Uniform Guidelines on Employee Selection Procedures* (Uniform Guidelines). A verified SECCM provides a valuable resource as a model that can be used for both key human resource functions as well as for the consistent career development of systems engineers. The SECCM is based on the Office of the Secretary of Defense (OSD) ENG Career Field Competency Model, currently used by the ENG acquisition community. The SECCM has enhanced the current ENG model through the addition of extensive sets of knowledge, skills, and ability (KSA) statements - each defined in terms of Bloom's taxonomy and mapped to each of the higher level system engineering competencies. Each competency and the associated KSAs are further partitioned into a series of typical career development points (i.e., from entry level to subject matter expert), to allow for planning and tracking of a competency-based development of systems engineers. This paper describes the development of the SECCM, and the current state of the competency model and verification process.

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Introduction

There is currently no professional engineering occupational code (08XX) for systems engineers. These occupational series each have a related competency model that can be used for human resource functions. Since there is no occupational series for SE, the Naval Postgraduate School (NPS) is developing a competency model for the profession of systems engineering. The systems engineering competency career model (SECCM) is a multi-year project funded by the Deputy Assistant Secretary of the Navy (DASN) for Research Development Test and Evaluation (RDT&E).

Competency is defined as "an observable, measurable pattern of skills, knowledge, abilities, behaviors and other characteristics that an individual needs to perform work roles or occupational functions successfully" (Office of Personnel Management [OPM]). *Competency modeling* is defined as the activity of determining the specific competencies that are characteristic of high performance and success in a given job (LaRocca, n.d.). According to Joshi et al. (2010), competency is defined as the ability to use the appropriate knowledge, skills, and abilities (KSAs) to successfully complete a specific job-related task. Systems engineering (SE) competencies are defined based on the knowledge, skills, and abilities—commonly referred to as KSA, KSAs, KSAA, or KSAB—that are necessary for a systems engineer to perform tasks related to the discipline. The SECCM will refer to the knowledge, skills, and abilities as KSAs. Proficient systems engineers are expected to be able to integrate, apply, and be assessed on these KSAs as they develop competencies through their education and training, professional development, and on-the-job experience (Khan, 2014).

To define the attributes of a "good" competency model, we cite the Holt and Perry (2011) guide. The Holt and Perry guide states that a good competency model "goes through many iterations, focuses on a specific aspect of competency yet is also simple and easy to understand, maps competencies across levels, and maps levels in a way that is easy to follow and emphasizes technical skills." In addition, a good competency model serves as a platform by which individuals can assess their skill set (Holt & Perry, 2011).

Many organizations within the Department of the Navy (DoN) and Department of Defense (DoD)—both the services and 4th Estate—have SE competency models that are locally "verified" or "validated" for their own individual use. These uses include career development, tracking education and training, and understanding the work-related activities that systems engineers have to accomplish. These SE competency models have been verified or validated locally in the sense that they have proven useful in their operational environment to define what their systems engineers do. There is, however, currently no SE competency model verified in accordance with the *Uniform Guidelines on Employee Selection Procedures* (Uniform Guidelines; Biddle Consulting Group, 2013). Only a model that is validated with the Uniform Guidelines can be used with confidence for all human resource (HR) functions, especially for "high stakes" functions like hiring, selection, writing position descriptions, and creating job announcements. Due to the importance of having a model verified for HR functions, DASN (RDT&E) extended the invitation to sister components and the Missile Defense Agency (MDA) to participate in the model verification process in an effort to make a model that is useful for all of the DoD.

The SECCM is based on the Engineer (ENG) Career Field Competency Model currently used by the ENG acquisition community to maintain consistency within the DoD. This multi-part ENG competency model addresses both core analytical, technical program management, business acumen, and professional competencies (Delgado, 2014).

The SECCM has enhanced the current ENG model through the addition of extensive sets of KSAs mapped to each of the higher level SE competencies, defined over a series of typical career development points. Members of the NPS SECCM team worked with the National Defense Industries Association (NDIA) SE working group (WG) over the past several years to help create the initial ENG Career Field Competency Model. The SECCM then added KSA details from several other existing systems engineering competency models, many provided to the original NDIA SE WG, from a variety of organizations.

The main objective of the SECCM project is to develop a verified systems engineering career competency model that can be used as a foundation for establishing construct validity for SE related human resources actions. To ensure the SE competency model will be able to be used this way, the SECCM research team is having the OPM use a standard approach to verify the occupational analysis in compliance with the Uniform Guidelines. Such a verified SECCM provides a valuable resource as a model that can be used for both key human resource functions as well as for the consistent career development of systems engineers.

SECCM Development Methodology

Several competency models were used to create and iterate the SECCM development in an effort to combine information from existing sources to generate as complete a scope of SE KSA as possible. The ENG (formerly SPRDE) Career Field Competency Model was used as a basis for the set of baseline competencies for the SECCM. The SECCM development then iterated through a series of modifications to the ENG model to a final form developed through verification by naval system command subject matter experts (SMEs).

Existing Systems Engineering Model Sources

Sources for the competency models used as the baseline for the SECCM include the International Council on Systems Engineering (INCOSE) United Kingdom (UK), Boeing, The National Aeronautics and Space Administration (NASA), Defense Acquisition University (DAU) Systems Planning, Research, Development, and Engineering (SPRDE), Naval Aviation Systems Command (NAVAIR), MITRE, Boeing, Space and Naval Warfare Systems Command (SPAWAR), and the Naval Underwater Warfare Center (NUWC) Newport. Collectively, once the various sets of competencies were collected and organized by affinity, the original SECCM consisted of 32 competencies. Of these, 29 were identical to the original SPRDE competencies (White, 2014). The next step in developing the original SECCM was to identify any KSAs associated with these 32 SE competencies. Only three of the existing models (NUWC, INCOSE UK, and MITRE) had significant levels of detail to allow the identification of KSA. In order to add additional depth in the identification of KSA, the DAU SPRDE Level I, II, and III course learning objectives were transformed into KSAs and added to the SECCM. Each entry, or KSA, from these sources was then used to build the baseline SECCM.

The harmonized set of KSAs was analyzed and re-organized based on the affinity with the respective competencies. The KSAs from each of the four sources were re-aligned to fit the SECCM by first eliminating duplication, then eliminating items that did not seem to be explicitly defined as a relevant SE competency, and lastly by re-organizing all of the KSAs into an appropriate competency. Figure 1 is an illustration of the existing competency models that were used to create the SECCM. Figure 2 shows the models used to derive the SECCM KSAs.

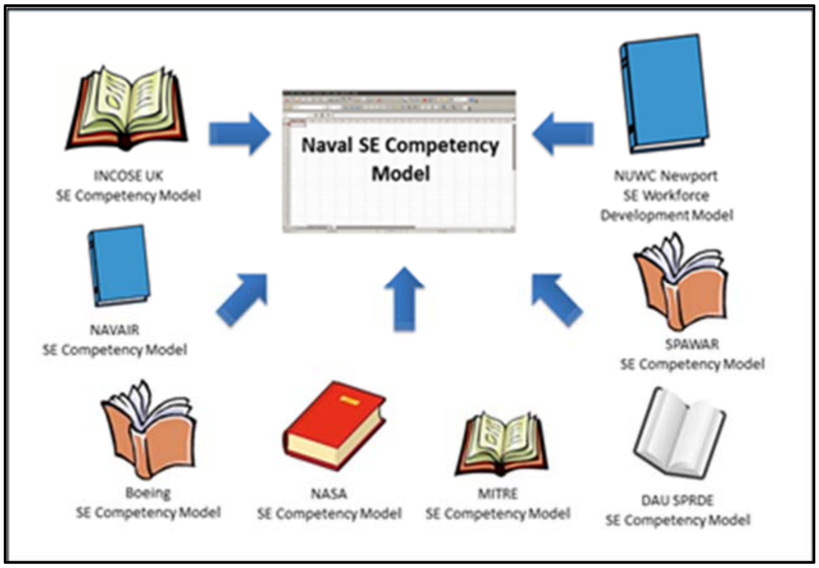

Figure 1. Competency Sources Used in the SECCM

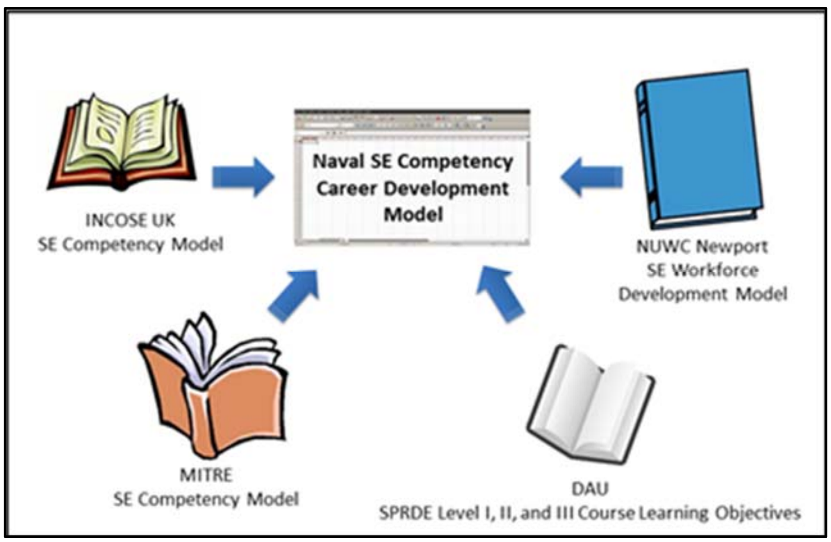

Figure 2. Models Used to Derive the SECCM KSAs

An NPS WG compared the 32 SECCM competencies with the 29 in the SPRDE model. The WG decided that two of the three additional competencies were more related to contracting, and one was specific to systems thinking, so these three competencies were eliminated as high level competency categories, and the associated KSA moved under the existing 29 competencies to align with the SPRDE model. Although the SECCM had aligned with this SPRDE model, it was subsequently updated and changed significantly by the OSD in 2013, with further changes in 2015.

Acquisition Workforce Career Fields SPRDE-SE, PSE, and ENG

> *The pure-and-simple politics of acquisition education is that many have viewed it as a deficient system that has failed to make clear what all students need to learn and whether, in fact, they have learned it. … The most fundamental problem is our schools are accountable only for educational*

processes, not educational outcomes.
Professor Robert L. Hawkings, Director of Curriculum Development, DAU

In June 2013, the SPRDE Career Field Competency Model was refreshed by an OSD-led working group. The resulting model consists of 41 competencies partitioned into four units of competence. The SECCM was updated by remapping the existing KSAs from the 29 SPRDE competencies to the new 41 competencies. The new SPRDE model was further decomposed into 84 sub-competencies aligned to the competencies, with the 41 high level competencies shown in Table 1.

Table 1. The 2013 Refresh DAU ENG Competencies

ENG Career Field Competency Model's Units of Competence	
Competency Number	**Unit of Competence: Analytical**
1.0	Mission Level Assessment
2.0	Stakeholder Requirements Definition
3.0	Requirements Analysis
4.0	Architecture Design
5.0	Implementation
6.0	Integration
7.0	Verification
8.0	Validation
9.0	Transition
10.0	Design Considerations
11.0	Tools and Techniques
	Unit of Competence: Technical Management
12.0	Decision Analysis
13.0	Technical Planning
14.0	Technical Assessment
15.0	Configuration Management
16.0	Requirements Management
17.0	Risk Management
18.0	Data Management
19.0	Interface Management
20.0	Software Engineering
21.0	Acquisition
	Unit of Competence: Professional
22.0	Problem Solving
23.0	Strategic Thinking
24.0	Professional Ethics
25.0	Leading High-Performance Teams
26.0	Communication
27.0	Coaching and Mentoring
28.0	Managing Stakeholders
29.0	Mission and Results Focus
30.0	Personal Effectiveness/Peer Interaction
31.0	Sound Judgment
	Unit of Competence: Business Acumen
32.0	Industry Landscapes
33.0	Organization
34.0	Cost, Pricing, and Rates
35.0	Cost Estimating
36.0	Financial Reporting and Metrics
37.0	Business Strategy
38.0	Capture Planning and Proposal Process
39.0	Supplier Management
40.0	Industry Motivation, Incentives, Rewards
41.0	Negotiations

The competency changes between the original SPRDE and the June 2013 refresh are outlined in Table 2.

Table 2. Summary of Competency Changes Between the SPRDE Career Field and ENG Career Field Competency Models

Summary of Competency Changes between the SPRDE Career Field and ENG Career Field Competency Models			
Added Competencies	**Removed Competencies**	**Re-phrased Competencies**	
		OSD SPRDE (Original)	**OSD ENG (Update)**
Mission Level Assessment	Safety Assurance	Technical Data Management	Data Management
Cost, Pricing & Rates	System Assurance	Systems Engineering Leadership	Leading High-Performance Teams
Design Considerations	Reliability, Availability & Maintainability (RAM)		
Tools and Techniques	Technical Basis for Cost		
Data Management	Modeling and Simulation		
Leading High-Performance Teams	System of Systems		
Coaching and Mentoring			
Managing Stakeholders			
Mission and Results Focus			
Personal Effectiveness/Peer Interaction			
Sound Judgment			
Cost Estimating			
Industry Landscapes			
Organization			
Financial Reporting and Metrics			
Business Strategy			
Capture Planning and Proposal Process			
Supplier Management			
Industry Motivation, Incentives, Rewards			
Negotiations			

While DAU designed and implemented their training programs that satisfy DAWIA requirements, the outcomes of those training programs are not necessarily targeted to the general, holistic university-level education of systems engineers for the SE workforce

(Alexander, 2013). The overarching problem is whether or not systems engineering competencies are being sufficiently developed in the SE workforce.

In October 2013, Under Secretary of Defense (AT&L) Frank Kendall III authorized the sunsetting of the SPRDE-PSE career field and transitioned all engineers in the SPRDE-PSE and SPRDE-SE career paths to a consolidated acquisition workforce career field titled "Engineering" (Kendall, 2013).

The DAU certification requirements for the new ENG career field are somewhat more substantial than the previous two SPRDE career fields, adding a few additional classes to the core requirements. A comparison of the core course requirements for 2013 SPRDE-SE Levels I, II, and III and 2015 ENG Levels I, II, and III are shown in Table 3. The old SPRDE-PSE career field certification required courses are shown in addition to SPRDE-SE requirements. There is no inclusion of the specific SPRDE-PSE requirements into the new ENG requirements.

Table 3. Course Requirements for DAU Certification

2013 SPRDE-SE	Course	
SE LEVEL 1	ACQ 101	Fundamentals of Systems Acquisition Management
	SYS 101	Fundamentals of Systems Planning, Research, Development and Engineering
	CLM 017	Risk Management
SE LEVEL 2	ACQ 102A	Intermediate Systems Acquisition, Part A
	ACQ 102B	Intermediate Systems Acquisition, Part B
	SYS 202	Intermediate SPRDE, Part I
	SYS 203	Intermediate SPRDE, Part II
	CLE 003	Technical Reviews
SE LEVEL 3	SYS 302	Technical Leadership in Systems Engineering
	CLL 008	Design for the supportability in DoD Systems

2015 ENG		
ENG LEVEL 1	ACQ 101	Fundamentals of Systems Acquisition Management
	SYS 101	Fundamentals of Systems Planning, Research, Development and Engineering
	CLM 017	Risk Management
	CLE 101	Value Engineering
	CLE 004	Intro to Lean Enterprise Concepts
ENG LEVEL 2	ACQ 202	Intermediate Systems Acquisition, Part A
	ACQ 203	Intermediate Systems Acquisition, Part B
	SYS 202	Intermediate SPRDE, Part I
	SYS 203	Intermediate SPRDE, Part II
	CLE 003	Technical Reviews
	LOG 103	Reliability, Availability and Maintainability
ENG LEVEL 3	SYS 302	NOT REQUIRED
	CLL 008	Design for the supportability in DoD Systems
	CLE 068	Designing for Supportability in DoD Systems DoD
	CLE 012	Open Systems Architecture
	ENG 301	Leadership in Engineering Defense Systems

In addition to the development of a new DAU curriculum to match the new ENG career field, the former SPRDE model was renamed as the ENG Career Field Competency Model in the same action in October promulgated by the OSD. At the time, no changes were made to the June 2013 refresh SPRDE model contents. In February 2015, however, a new OSD WG was formed to refresh the ENG Career Field Competency Model. The transition from the original pre-2013 SPRDE Career Field Competency Model to the current ENG Career Field Competency Model is summarized graphically in Figure 3. This 2015 model update is still in process as of April 2015.

Figure 3. SPRDE to ENG Transition

Competency Classification Verification

The current SECCM competencies align with the ENG Career Field Competency Model 2015 version. The leading verb phrases in the statements of the KSA within the competencies have been redefined using key words from Bloom's taxonomomic classicifcation schema. This naturally partitioned them further into specific cognitive or affective categories found within Bloom's schema. Specifically, the version of Bloom's taxonomy as adapted by Krathwohl (2002), shown in Figure 4, was used for the cognitive and affective learning domains.

Figure 4. Bloom's Taxonomy Cognitive Domain From Krathwohl (2002)
(MMI, n.d.)

The significance of using Bloom's taxonomic classification schema is that in research, how engineering students learn is often categorized using Bloom's taxonomy. For instance, engineering education involves learning objectives, which are typically organized around Bloom's taxonomy of cognitive and affective processes. The cognitive domain involves knowledge and the development of intellectual skills, whereas the affective domain deals with the motivations and attitudes involved in learning (Clark, 1999). Cognitive and affective processes within Bloom's taxonomy refer to levels of observable actions that indicate learning is occurring.

Bloom's taxonomy provides hierarchical outcome categories or levels that range from simple to complex thought processes. Once the Bloom's level for each KSA was identified, each of the KSAs were mapped to one of three notional career levels designated as SE-01 Entry Level, SE-02 Journey Level or SE-03 Expert Level, as shown in Figure 5. The KSAs generally attributed to lower level Bloom's learning process were mapped into SE-1 Entry Level, the KSAs with intermediate level Bloom's learning processes were mapped into SE-2 Journey Level and the KSAs with higher level Bloom's learning processes were mapped into the SE-3 Expert Level. In an effort to create a foundation for SE career development within the DON, the KSAs were then mapped into competencies across proficiency levels.

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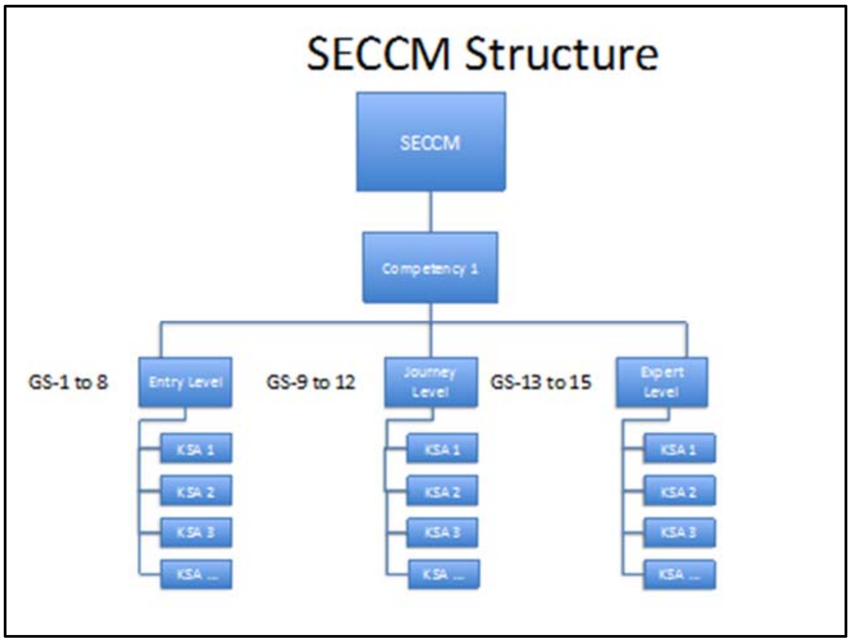

Figure 5. Typical SECCM Career Development Levels

The alignment of KSAs to competencies is just a notional starting point, as the research team intends that any assignment of various KSAs to different career development levels can be conducted by an organization in its own specific implementation of the SECCM as a career competency development tool.

A baseline review conducted by SMEs verified that the KSAs were aligned to reasonable competencies. As a result of the WG effort, if a group consensus was that a KSA was not aligned to an appropriate competency, the KSA was re-assigned to one deemed more appropriate by the SMEs. The baseline review also identified some KSAs that did not belong in the model. If the SMEs and stakeholders on the SECCM team felt that a KSA did not apply to an SE application, the KSA was eliminated from the model. In some instances, SMEs added KSAs to the model based on their experience. Following this iterative process, redundant KSAs were deleted and vague KSAs were re-written. In an effort to enforce consistency in the model (while also properly using Bloom's taxonomic classification schema), each KSA was updated to have an action verb at the very beginning of the sentence. The verbs were all converted to present tense for consistency (Whitcomb, Khan, & White, 2014).

Compliance With Uniform Guidelines

Now that the competency model for professionals performing systems engineering activities is developed, the next step is to finalize the model through an occupational analysis. The Office of Personnel Management's (OPM) Leadership and Workforce Development Assessment (LWDA) team has joined the Naval Postgraduate School and SMEs[1] to assist in the refinement, confirmation, and strategic planning required to ensure the systems engineering competency model is a legally defensible, relevant, and sound tool that may be used for a variety of human resources purposes (e.g., career path modeling, skills gap assessment, selection tool development). To ensure the competency model will be able to serve as the foundation for establishing content verification for future human resources actions, OPM uses an approach to the occupational analysis in compliance with the Uniform Guidelines. This approach gathers input from SMEs through panels and an occupational analysis survey.

Outline of OPM Occupational Analysis Methodology

Beginning with the model created by NPS, the OPM is taking a four-pronged approach to the occupational analysis: review of occupational information, facilitation of SME panels, administration of surveys, and documentation. The occupational analysis methodology focuses on identifying the competencies and tasks that are critical for employees functioning as systems engineers. This method of occupational analysis establishes which competencies are suitable for assessment in human resources activities.

The OPM began the occupational analysis with a review of the SECCM along with additional occupational information provided by NPS and other DoD components, including the MDA. The occupational information served to further define the competencies included in the existing NPS model. Adding descriptions to the competencies serves to ensure each competency included in the model is clear and unique. The OPM also conducted an initial review of the KSAs included in the SECCM to refine the list. LWDA personnel research psychologists removed or revised KSAs that were not behaviorally based or measurable characteristics to ensure the resulting task statements had the characteristics necessary to support a variety of human resources activities.

LWDA personnel research psychologists then facilitated SME panels to further refine the SECCM. Panels were held first with incumbents who currently perform systems engineering activities and then with individuals who supervise those who perform systems engineering activities. NPS recruited SMEs to participate in the panels, requiring SMEs to

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[1] SME teams consisted of incumbents and supervisors across the Department of Defense (DoD) who either currently engage in or supervise systems engineering activities.

meet experience criteria to ensure each SME had a minimum level of familiarity with systems engineering activities. SMEs provided input to further revise competency definitions and task statements, identify competencies and tasks critical to systems engineering which were not represented in the existing model, and eliminate tasks not representative of the job.

The revised competencies and tasks will serve as the foundation for an occupational analysis survey. The OPM will invite employees who perform systems engineering activities and their supervisors to participate in the survey, only retaining data from employees with minimum experience levels to ensure adequate familiarity with systems engineering work. The OPM will further ensure that participants in the survey have relevant experience by asking NPS to identify the population and by confirming each participant's experience through survey branching methodology. The survey branching will require participants to respond to questions designed to distinguish participants who function as a systems engineer from those who serve in other engineering disciplines. Survey participants will evaluate each competency and task in the SECCM on criteria such as frequency, importance, required immediately upon entry into the position, and need for training.

LWDA personnel research psychologists will conduct statistical analyses on the survey data to determine which competencies and tasks are critical to the successful performance of systems engineering activities. To identify the critical tasks, the research psychologists will analyze task ratings of frequency and importance. Competencies critical for performing systems engineering activities will be identified by analyzing competency ratings of importance and need at entry. The resulting critical tasks and competencies will make up the occupational profile for individuals performing systems engineering work.

In conformance with legal and professional guidelines, the OPM will document the methodology and results for all phases of the occupational analysis. The documentation is a necessary component for demonstrating that the process is sufficient to serve as a component of a content validation approach[2] for ensuring the validity of future human resources activities.

Identifying SE Population

Identifying the population of systems engineers in any organization is currently a challenge faced by the DoN and other defense organizations. The SE population is needed to identify those SE to include in the survey pool. The SE population is identified based on input from all participating organizations. There is no single best way to identify a systems engineer, so each organization must attempt to identify their own population based on identifying engineers who perform tasks related to SE. The population is required to complete the cost estimate document that is required to obtain DoD Survey approval. Approval is in process and will be obtained prior to deploying the survey.

[2] "Evidence of the validity of a test or other selection procedure by a content validity study should consist of data showing that the content of the selection procedure is representative of important aspects of performance on the job for which the candidates are to be evaluated" (Biddle Consulting Group, 2013).

Relationship to DCAT

The Defense Civilian Personnel Advisory Service (DCPAS), Strategic Human Capital Planning Division (SHCPD) is responsible for the implementation of the DoD competency-based approach for workforce planning. This approach includes competency model development for mission critical occupations and all major occupational series, assessment of civilian workforce competency gaps, and identification of civilian workforce competencies needed now and into the future. This initiative supports the DoD's ability to meet the legislative requirements established in 10.U.S.C 115b. The DoD designed, developed, and deployed the Defense Competency Assessment Tool (DCAT) as a Department-wide, online tool to validate occupational competency models and assess civilian employees' proficiency levels and competency gaps.

Employees are selected to participate in DCAT through a stratified random sample process based on civilian employee grade and particular occupational series being assessed. DCAT interfaces with the Defense Civilian Personnel Data System (DCPDS); this feature limits DCAT use to occupations classified under the U.S. Standard Occupational Classification System.

DCAT assesses civilian employees by their individual series' competency model, not by functional competency models. Since the System Engineering discipline is a functional career field that cuts across multiple occupational series, currently DCAT does not have the capability to assess the SECCM, so the OPM was brought in to the SECCM team to accomplish the verification process.

SECCM Implementation

The SECCM is implemented in a spreadsheet format to make it easy to manipulate based on any desired outcome for customization of a competency model within any defense organization. The goal is that an organization can use the model as a foundation and have an opportunity to customize it to meet the needs of the organization. The SECCM is a great tool to use because a baseline review of the model by organizations across the DoD has been completed. The baseline review was completed to certify that the KSAs were clearly defined and applicable. As previously mentioned, the 41 competencies in the SECCM mirror the competencies identified in the ENG Career Field Competency Model. The KSAs in the model were taken from several other successful existing competency models. These KSAs were re-written, categorized into blooms levels of cognitive and affective domains, and organized prior to adopting them into the SECCM. One organization, the Space and Naval Systems Center (SSC) Atlantic, has implemented their SE competency model using the SECCM. In addition, the NPS SECCM project team is collaborating as members of the International Council on Systems Engineering (INCOSE) Competency Working Group (CWG) to develop an INCOSE SE competency model.

SPAWAR Uses SECCM

SSC Atlantic was recently challenged to establish a competency development model for systems engineers. As of March 2015, SSC Atlantic consists of close to 4,000 U.S. government employees—approximately 900 of which can be considered systems engineers. Over 240 integrated product teams (IPTs) in SSC Atlantic work to deliver various IT-related end item products to Naval, Joint and Coalition warfighting customers. The range of engineering processes, technologies, missions, and customers supported by the SSC Atlantic engineering department covers a wide spectrum. In order to better understand the KSAs required for a systems center, KSAs were organized into competency dimensions—process, technology, and mission (excluding leadership skills for the sake of this paper as they apply to everyone—not just systems engineers). Having a robust set of competency areas for each of these dimensions helps ensure that systems engineers are well rounded in order to provide technical leadership to multi-disciplinary teams with role-diverse team members (Walter, 2013).

Within each dimension, competency areas were defined and prioritized based on a standard set of SE use cases most commonly experienced at SSC Atlantic, as well as based on DoD and industry standards. High prioritization of competency areas associated with requirements, architecture design, software engineering, and system assurance highlights the importance for sound up-front systems engineering process execution, IT systems' increasing reliance on software, and the paramount need for cybersecurity. By defining subroles (or specialty areas) for a systems engineer, further KSAs were defined that stress certain competency areas over others. Identifying relevant and authoritative competency areas and KSA sources for a competency framework is critical, as there is no need to recreate data that has already been adequately developed by several other relevant and established industry and DoD organizations. Competency areas and KSAs from the Naval SECCM were heavily used to populate the SSC Atlantic systems engineer competency development model—particularly in the SE process dimension. For the purposes of developing an SE competency framework for SSC Atlantic, the SECCM provides a wide array of KSAs from which to choose, along with recommended competency development model (CDM) stages (levels) for each individual knowledge, skill, or ability. Due to SSC Atlantic's mission focus on IT and cyberspace, the NIST national cybersecurity workforce framework also proved highly useful in tailoring an SE competency framework. Several other competency frameworks and sources were used to a lesser degree to populate the underlying KSA database used for roles all across SSC Atlantic.

In order to establish a complete set of KSAs at each competency development stage, a layered-cake approach was taken, meaning that KSAs are applicable to an increasingly narrowed sector of individuals. For example, Figure 6 shows how every SSC Atlantic employee needs leadership skills, members of the entire engineering department (a.k.a. "competency") require "core" engineering skills, all systems engineers require a certain set of KSAs, and then specific sub-roles or types of systems engineers require yet a separate set of KSAs. Each of these KSA sets is ultimately part of a systems engineer's competency development model. In order to establish systems engineering roles that could be well understood across the organization, we also examined the roles that interact with a systems engineer in order to determine where KSAs should be shared across the roles or unique to one or the other.

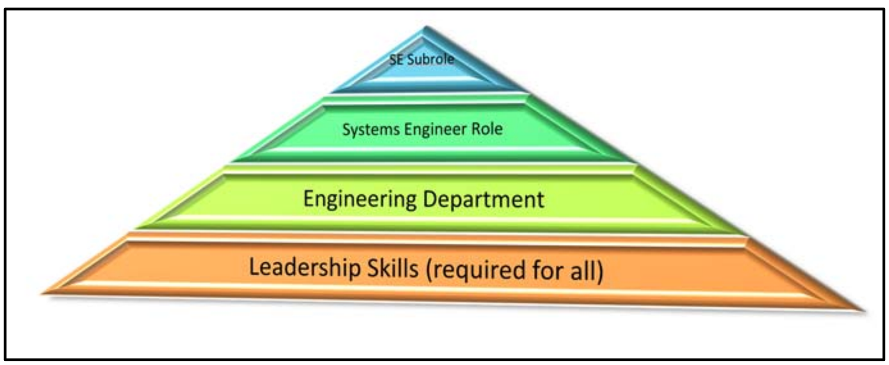


Figure 6. SSC Atlantic SE Competency Framework KSA Pyramid

Analysis was conducted to understand *how* these KSAs can and should be obtained. The most common methods for an individual to obtain a KSA are through educational training (DAU, degrees, or certifications), in-house-developed training courses/workshops, and on-the-job training (OJT). DAU engineering classes can be effective when providing systems engineers with basic knowledge and comprehension of the SE life cycle processes—particularly in the areas of acquisition and risk management. OJT can be enhanced when coupled with targeted rotational opportunities and job shadowing opportunities. If approached systematically, immeasurable value can be obtained from developing in-house SE training that engages systems engineers at all levels of the workforce. When assessing the competency of systems engineers, care was taken to choose an assessment process and associated assessment methodologies that were relatively thorough yet not overly cumbersome, time-consuming, and costly.

From the perspective of an individual desiring to develop over the course of their career in the role of a systems engineer, they are provided with guidance on how to do so. Figure 7 illustrates how SSC Atlantic systems engineers seek to better understand their role and CDM; complete a CDM self-assessment package where they address each required KSA; review feedback from a competency assessment panel regarding their KSA gaps; complete an individual development plan which defines what developmental activities and training they plan to take in order to satisfy each KSA; complete their training and/or developmental activities; update their IDP; and then submit for reassessment against the CDM. From the perspective of a competency manager or the training department, this provides a much more streamlined method for determining the required training for SSC Atlantic, as training and developmental activities can be targeted directly at the KSA gaps of the workforce.

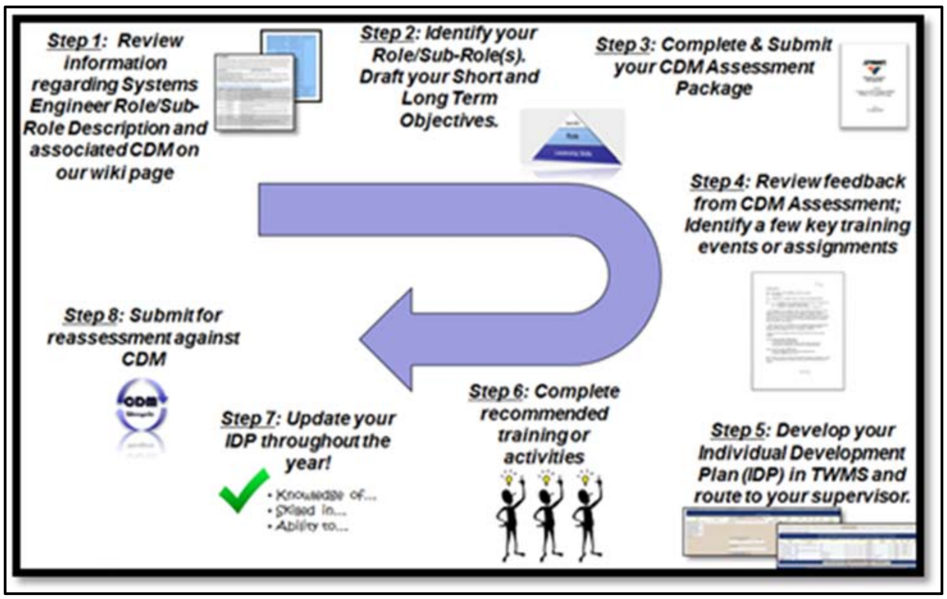


Figure 7. SSC Atlantic SE Competency Model Development

Relationship to INCOSE Competency Model Development

The NPS SECCM project team is collaborating with the INCOSE CWG to develop a new INCOSE SE Competency Model. An initial evaluation of the transfer of SECCM KSAs into the INCOSE SE Competency model (draft version), reveals that almost half (49%) of the SECCM KSAs are in the lowest level of cognitive and affective learning domains of *Remember, Understand, Receive Phenomena & Respond to Phenomena*. Overall, the majority (66%) of the SECCM KSAs, as aligned with the INCOSE competencies, are mapped to the cognitive domain. The remaining (34%) KSAs are mapped into the affective domain. Figures 8 and 9 illustrate the percentage of cognitive and affective KSAs as captured in the SECCM, by learning domain.

Figure 8. Count and Percentage of Cognitive KSAs Within SECCM

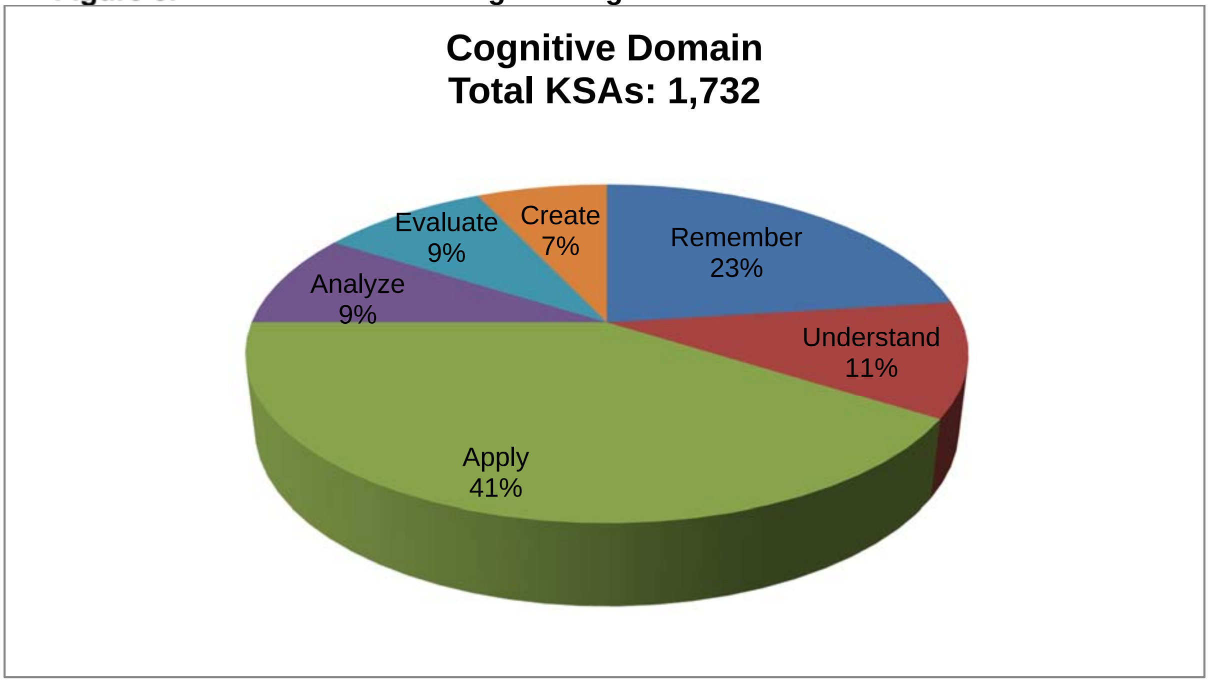
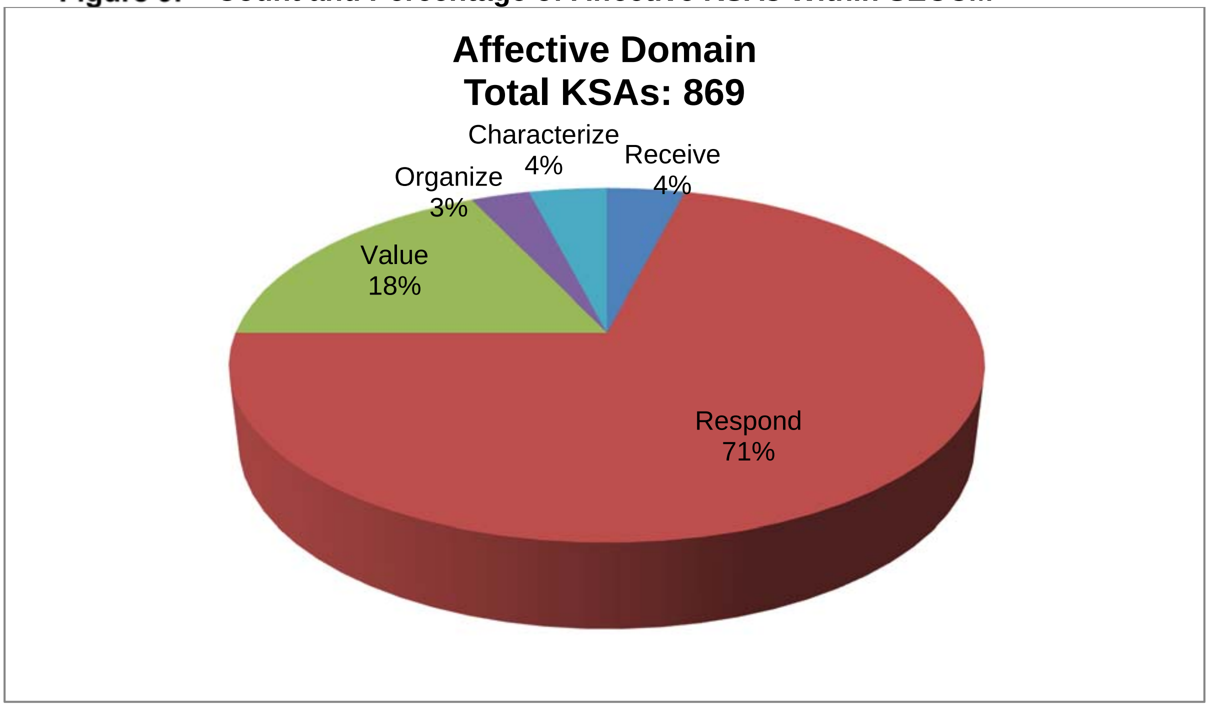


Figure 9. Count and Percentage of Affective KSAs Within SECCM



In assessing the draft results of the transfer of SECCM KSAs into the INCOSE SE competencies, it can be seen that SEs need to be highly competent in KSAs related to the cognitive domains of *Concurrent Engineering, Design Considerations/Specialty Engineering, Lifecycle Process Definitions* and *Technical Assessment and Control.* Similarly, observations regarding the results of the affective domain processes show that *Leadership* and *Team Dynamics* are important requisite Systems Engineering competencies. These findings are detailed in Table 4.

Figure 10. Transfer of SECCM KSAs into INCOSE competencies (draft): Count of Cognitive and Affective KSAs

INCOSE Competency	Count of KSAs	
	Cognitive	Affective
Acquisition	11	
Architecture Definition	30	2
Communication	31	66
Concurrent Engineering	128	57
Configuration Management	61	21
Critical Thinking	98	40
Decision Management	76	24
Design Considerations/Specialty Engineering	142	64
Engineering and Scientific Fundamentals	12	
Enterprise Integration	1	
Ethics	17	24
Implementation	19	23
Information Management	13	
Integration	18	6
Integration	20	16
Integration of Specialisms	3	
Interface Management	58	11
Leadership	78	157
Lifecycle Process Definition	308	43
Mathematics/Logic/Quantitative Analysis	1	
Modeling & Simulation	62	22
Negotiation	3	
Reliability, Maintainability & Availability Analysis	6	1
Safety Analysis	2	
System Requirements Definition	63	29
Team Dynamics	29	120
Technical Assessment & Control	121	45
Technical Planning	64	5
Technical Risk Management	74	27
Transition	48	8
Validation	40	28
Verification	95	30
Total	**1,732**	**869**
Grand Total (Cognitive & Affective)		**2,601**

Summary

Progress on the SECCM has positioned the DOD as a leader in the human resources management aspect through this systems engineering competency modeling effort. The SECCM identifies a collection of KSAs that define the basis for developing effective systems engineers. The NPS research team contends that along with its applicability as a valuable resource as a model that can be used for key HR functions the SECCM can also be used to assist undergraduate and graduate academic programs in specifying student outcomes and learning objectives within systems engineering programs - to ensure students have the entry-level KSAs required to perform successfully once in the field. The implications of the research can also be used to develop structured curriculum content, assessment, and continuous process improvement techniques related to the development of SE learning, and to develop more valid and reliable instruments for assessing what systems engineers need to learn, need to know, and need to do.

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