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**THESIS**

**DEVELOPMENT OF SYSTEMS ENGINEERING  
COMPETENCY CAREER DEVELOPMENT MODEL:  
AN ANALYTICAL APPROACH USING BLOOM'S  
TAXONOMY**

by

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**DEVELOPMENT OF SYSTEMS ENGINEERING COMPETENCY CAREER  
DEVELOPMENT MODEL: AN ANALYTICAL APPROACH USING BLOOM'S  
TAXONOMY**

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## **ABSTRACT**

Systems engineering is vital for the acquisition of systems for the Department of the Navy (DON). As systems engineering is a relatively young discipline, no professional engineer occupational series exists under which systems engineers can be classified from a human resources perspective. In addition to the lack of an occupational designation, there is no official competency model to form the basis for employee selection and career development. In order for a competency model to be used for employee selection, it must be validated under the Uniform Guidelines for employee selection. Once validated, the model can be used to create systems engineering position descriptions and related career development plans that would be specifically used for systems engineers within the DON and perhaps for DOD. A baseline competency model is the first step in performing a validation process in accordance with the Uniform Guidelines.

In order to begin to address this situation, a system engineering competency model was developed to provide a baseline. This model was designed specifically for the DON, though it should also be useable in any organization that employs system engineers. The core of the model is based on the knowledge, skills, and abilities (KSAs) that a systems engineer needs to develop competency in across varying career levels. These KSAs are defined using Bloom's Taxonomy to describe, the cognitive and affective aspects needed for achievement of the respective competencies. The research also identifies whether these KSAs are best attained through specific methods, such as undergraduate education, graduate education, professional training, or through on-the-job experience. Furthermore, the model can inform the development of graduate and undergraduate curricula in systems engineering, since using Bloom's Taxonomy describes the KSAs in terms that lend themselves to direct use as curriculum related learning objectives.

The outcome is called the Competency Model for the Profession of Systems Engineering (COMPOSE) model. The COMPOSE model can be used by the DON and several other organizations as a means to formulate career development plans for the professional development of systems engineers.

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# TABLE OF CONTENTS

<b>I.</b>	<b>INTRODUCTION.....</b>	<b>1</b>
	<b>A. BACKGROUND .....</b>	<b>1</b>
	<b>1. Problem Background.....</b>	<b>1</b>
	<b>2. What Is Competency.....</b>	<b>1</b>
	<b>3. Competency Modeling.....</b>	<b>2</b>
	<b>B. PROBLEM STATEMENT .....</b>	<b>2</b>
	<b>C. RESEARCH OBJECTIVES .....</b>	<b>3</b>
	<b>D. RESEARCH QUESTIONS.....</b>	<b>3</b>
	<b>1. Primary Research Question .....</b>	<b>3</b>
	<b>2. Secondary Research Questions .....</b>	<b>4</b>
	<b>E. PURPOSE/BENEFIT .....</b>	<b>4</b>
	<b>F. SCOPE .....</b>	<b>4</b>
	<b>G. METHODOLOGY .....</b>	<b>5</b>
	<b>H. THESIS STATEMENT .....</b>	<b>5</b>
	<b>I. REPORT ORGANIZATION.....</b>	<b>6</b>
	<b>J. CHAPTER SUMMARY.....</b>	<b>6</b>
<b>II.</b>	<b>LITERATURE REVIEW .....</b>	<b>7</b>
	<b>A. BLOOM’S TAXONOMY .....</b>	<b>7</b>
	<b>B. SUCCESSFUL COMPETENCY MODELING APPROACHES .....</b>	<b>12</b>
	<b>C. EXISTING SE COMPETENCIES SERVE AS A FOUNDATION.....</b>	<b>14</b>
	<b>1. SE Workforce Development Naval Underwater Warfare Center Competency Model.....</b>	<b>16</b>
	<b>2. International Council on Systems Engineering United Kingdom Competency Model .....</b>	<b>17</b>
	<b>3. MITRE Competency Model.....</b>	<b>17</b>
	<b>4. Defense Acquisition University System Planning, Research, Development and Engineering Learning Objectives.....</b>	<b>18</b>
	<b>D. CHAPTER SUMMARY.....</b>	<b>18</b>
<b>III.</b>	<b>COMPETENCY MODEL DEVELOPMENT .....</b>	<b>19</b>
	<b>1. Evolution of the COMPOSE Model.....</b>	<b>21</b>
	<b>B. ALIGNING INFORMATION GATHERED .....</b>	<b>26</b>
	<b>C. SCREENING.....</b>	<b>29</b>
	<b>D. INCORPORATING DAU SPRDE CL/POS &amp; ELOS .....</b>	<b>29</b>
	<b>E. MAPPING TO FIT BLOOM’S TAXONOMY .....</b>	<b>32</b>
	<b>F. IDENTIFYING CAREER LEVELS.....</b>	<b>32</b>
	<b>G. IDENTIFYING POTENTIAL COMPETENCY LEARNING SOURCES.....</b>	<b>32</b>
	<b>H. COMPETENCY SUMMARY .....</b>	<b>33</b>
	<b>I. CHAPTER SUMMARY.....</b>	<b>33</b>
<b>IV.</b>	<b>DATA AND ANALYSIS .....</b>	<b>35</b>
	<b>A. PRIMARY RESEARCH: COMPOSE V0.78 DATA .....</b>	<b>35</b>

B.	ANALYSIS .....	38
C.	SUMMARY .....	38
V.	FINDINGS/RESULTS.....	39
A.	PRIMARY RESEARCH FINDINGS .....	39
B.	OTHER FINDINGS.....	45
C.	RESEARCH QUESTIONS FINDINGS .....	49
D.	CHAPTER SUMMARY.....	50
VI.	SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND FURTHER RESEARCH .....	51
A.	SUMMARY .....	51
B.	CONCLUSIONS AND RECOMMENDATIONS.....	52
C.	FURTHER RESEARCH.....	53
	APPENDIX A. EXAMPLES OF CAREER LEVELS FOR THE V0.78 COMPOSE MODEL .....	55
	APPENDIX B. SE COMPETENCY OBJECTIVES .....	59
	APPENDIX C. KRATHWOHL COGNITIVE AND AFFECTIVE DOMAINS..	61
	APPENDIX D. KENDALL’S MEMO.....	63
	INITIAL DISTRIBUTION LIST .....	67

## LIST OF FIGURES

Figure 1.	Bloom’s Taxonomy Domain (from Wrightstuffmusic 2014).....	6
Figure 2.	Changes to Bloom’ (from Wilson 2013) .....	8
Figure 3.	Krathwohl’s Bloom’s Taxonomy Update—Cognitive Domain (from Florida International University 2014) .....	11
Figure 4.	Competency Model Development Steps (from U.S. Department of Labor Employment and Training Administration 2013).....	14
Figure 5.	Competency Sources Used in COMPOSE ( from Whitcomb, Khan and White 2013) .....	15
Figure 6.	KSAs sources used in COMPOSE (from Whitcomb, Khan and White 2013) .....	16
Figure 7.	COMPOSE Career Development Levels.....	23
Figure 8.	Krathwohl’s Bloom’s Taxonomy (from MMI n.d.).....	24
Figure 9.	The COMPOSE Model Education, Training and On the Job Experience for Competency 11.0 Tools & Techniques Entry Career Level Example .....	25
Figure 10.	COMPOSE Model V0.78 .....	28
Figure 11.	Number of DAU SPRDE-SE CL/POs in each System Engineering Competency (from Alexander 2013) .....	30
Figure 12.	ENG KSAs within COMPOSE V0.78.....	31
Figure 13.	Breakdown of ENG KSAs across experience levels in the COMPOSE model V0.78.....	31
Figure 14.	COMPOSE Overall Model’s Cognitive and Affective Breakout.....	35
Figure 15.	Bloom’s Cognitive Levels within the COMPOSE Overall Model.....	36
Figure 16.	Bar Chart of Bloom’s Cognitive Levels within the COMPOSE Overall Model .....	36
Figure 17.	Bloom’s Affective Levels within the COMPOSE Overall Model.....	37
Figure 18.	Bar Chart of Bloom’s Affective Levels within the COMPOSE Overall Model .....	37
Figure 19.	Bloom’s Cognitive Levels within the COMPOSE model (SE-01).....	39
Figure 20.	Bloom’s Cognitive Levels within the COMPOSE model (SE-02).....	40
Figure 21.	Bloom’s Cognitive Levels within the COMPOSE model (SE-03).....	40
Figure 22.	Trend of Bloom’s Cognitive Levels within the COMPOSE model, the key is the same as Figures 19-21. ....	41
Figure 23.	Bloom’s Affective Levels within the COMPOSE model (SE-01) .....	42
Figure 24.	Bloom’s Affective Levels within the COMPOSE model (SE-02) .....	43
Figure 25.	Bloom’s Affective Levels within the COMPOSE model (SE-03) .....	43
Figure 26.	Trend of Bloom’s Affective Levels within the COMPOSE model, the key is the same as figures 23-25. ....	44
Figure 27.	SPAWAR Example.....	45
Figure 28.	KSAs from the COMPOSE model used by SPAWAR .....	46
Figure 29.	SPAWAR vs. COMPOSE model Cognitive Domain.....	47
Figure 30.	Cognitive Levels of DAU SPRDE-SE Level II Curriculum and NPS SE Competency Model (from Alexander 2013).....	48

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## LIST OF TABLES

Table 1.	Bloom’s Taxonomy of Educational Outcomes—Cognitive Domain (from GRCSE 2011, 97–98) .....	9
Table 2.	Bloom’s Taxonomy of Educational Outcomes—Affective Domain (from GRCSE 2011, 99–100) .....	10

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## LIST OF ACRONYMS AND ABBREVIATIONS

AWF	acquisition workforce
BKCASE	Body of Knowledge and Curriculum to Advance System Engineering
CDM	competency development model
CDIO	Conceive, Design, Implement, Operate
COMPOSE	Competency Model for the Profession of Systems Engineering
DAG	Defense Acquisition Guidebook
DASN	Deputy Assistant Secretary of the Navy
DAU	Defense Acquisition University
DOD	Department of Defense
DON	Department of the Navy
ELO	Enabling Learning Objective
ENG	engineering
GRCSE	Graduate Reference Curriculum for Systems Engineering
INCOSE	International Council on Systems Engineering
KSAs	knowledge, skills and abilities
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Air Systems Command
NPS	Naval Postgraduate School
NUWC	Naval Underwater Warfare Center
OSD	Office of the Secretary of Defense
PCD	Position Category Description
PSE	Program Systems Engineering
RDT&E	Research, Development, Test and Engineering
SE	systems engineering
SME	Subject Matter Expert
SPAWAR	Space and Naval Warfare Systems Command
SPRDE	Systems Planning, Research, Development and Engineering
SSC	Space Systems Center

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## EXECUTIVE SUMMARY

The Competency of the Profession of Systems Engineering (COMPOSE) model was designed to assist with career development modeling and creating position descriptions for the Department of Defense (DOD) (Whitcomb, Khan, & White, 2013). It can also assist graduate academic programs to specify objectives within systems engineering (SE) programs that will ensure the students have the entry-level knowledge, skills and abilities (KSAs) required to perform successfully in their job. Training levels and competency sources are identified within the model. Each KSA was mapped and analyzed using a Bloom's Taxonomy cognitive and affective domain approach. This approach provides an interactive model that determines the KSAs required for DOD systems engineers to be considered competent at various career experience levels.

The COMPOSE model encompasses eight different documented systems engineering competency models from a variety of organizations. These other competency models 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. The COMPOSE model uses these eight models as a foundation. The KSAs are harmonized with Bloom's Taxonomy based on affinity in the KSAs. The KSAs are also realigned to maintain consistency in the COMPOSE model by eliminating duplication; items that do not fit are re-categorized based on how each KSAs is written. In the beginning, after initially combining each of the models, there were 2,151 KSAs and 31 competencies. Based on the realignment and re-categorization, the COMPOSE 0.78 model has a total of 41 competencies and 2,914 KSAs.

The KSAs within the COMPOSE model are also characterized to align with either the technical/ technical management or the professional competencies. Analysis results indicate that when it comes to technical/technical management competency within

systems engineering, at entry-level positions (SE-01) lower level KSAs from the cognitive domain are required. As the career level increases, so does the complexity of the KSAs within the cognitive domain. The opposite is true for professional competence within the SE domain; at entry-level positions, KSAs within the affective domain are needed to be competent. The majority of the KSAs are knowledge and comprehension based within the cognitive domain, which makes sense since these are lower level cognitive domains that can be learned by training and education. As the career progresses in journey-level (SE-02) and expert level (SE-03) career levels, the focus shifts to application. At this stage in the career development, the individual is required to apply what was learned to do his/her job. This means that all expert level SE position descriptions should substantially highlight application.

#### **LIST OF REFERENCES**

Whitcomb, Clifford, Rabia Khan, and Corina White. 2013. "Systems Engineering Competency Report" Paper presented to the Systems Engineering Stakeholders Group, Washington, DC.

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## I. INTRODUCTION

This chapter will define competency and explain why it is relevant to study for systems engineering (SE). It will also share the attributes found in a good competency model, while identifying how the Competency Model for the Profession of Systems Engineering (COMPOSE) has evolved.

The Systems Planning, Research, Development and Engineering (SPRDE) career field has approximately 38,000 employees (Lasley-Hunter and Alan 2011). There is currently no professional engineering occupation code or position description for SE within the Department of Defense (DOD). This makes it very difficult to identify how many systems *engineers* are within the DOD from within this 38,000-member SPRDE workforce.

### A. BACKGROUND

#### 1. Problem Background

There is currently no professional engineering occupational code or position description for SE within the DOD. Professional engineering occupational codes are used to classify the characteristics desired for various engineering communities, such as chemical engineers or mechanical engineers, for instance. Occupational codes also provide a government job resource that can assist in determining the number of employees in a specific field or occupation. Occupational codes can also assist with manpower forecasting efforts. Position descriptions highlight the KSAs required to be qualified for a specific job. The position descriptions are helpful with finding the most competent candidate for the position. There is a need for a competency model offering a set of KSAs that will assist in creating position descriptions and a related SE career development plan designed specifically for systems engineers within the DON.

#### 2. What Is Competency

According to (Joshi, Datta and Han 2010), competency is the ability to use the appropriate KSAs to complete successfully a specific job-related task. When combining

competency with competence, it introduces competency assessment. Competency assessment is a tool found useful to organizations for allocating human resources for a successful employer-employee match. Competency assessment is also beneficial in creating job-specific professional development and accurate training requirements for employees to obtain a good match for the position. Joshi's study examined hiring practice trends through content analysis of job advertisements and job types and observed that corporations prefer to employ well-rounded employees with business knowledge, interpersonal skills and technical skills.

### **3. Competency Modeling**

Important to this research was the role of competency modeling, which 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.) A good competency model has the following attributes: it has gone through much iteration; it focuses on a specific aspect of competency; it is simple and easy to understand; and it maps competencies across levels (Holt and Perry 2011). The model should map career levels in a way that is easy to understand. For example, if a given organization's standards require that an individual attain the "practitioner" level for a competency, then it is assumed that the individual must hold that competency when at "supervised practitioner" level also. In addition, a good competency model serves as a platform by which individuals can assess their skill set (Whitcomb, Khan and White 2013).

#### **B. PROBLEM STATEMENT**

Currently, there is no Position Category Description (PCD) for a systems engineer within the Naval System Command. PCDs have KSAs necessary to complete a job. KSAs for systems engineers within the command vary depending on their professional and educational background, experience, and domain specialization at various career levels.

In order to solve this problem, KSAs required to be a competent systems engineer at various career experience levels were identified. After the KSAs identification, the KSAs origin was determined. Does it originate from undergraduate education, on the job

training or professional development courses? Then each SE career experience level was identified and related to the required KSAs. This effort resulted in a foundation to build a SE career development plan that can be truly beneficial to both the Navel engineer professional and the DOD.

### **C. RESEARCH OBJECTIVES**

The objectives for this research are to use the COMPOSE model that the NPS Team created to develop a competency model and identify and evaluate the cognitive and affective domains associated with SE KSAs. The affective domain has to do with emotions, feelings and attitudes. Objectives describe growth in awareness, attitude, emotion, changes in interest, judgment and the development of appreciation. Harmonizing the COMPOSE model with Bloom's Taxonomy creates the baseline information needed for the COMPOSE while defining career paths for systems engineers.

### **D. RESEARCH QUESTIONS**

The following research questions were developed to guide the research and address the research objectives. The answers and conclusions from the analysis are presented in Chapters IV and V.

#### **1. Primary Research Question**

The primary research question will help determine the attributes that a naval systems engineering competency model would need to be useful to naval system commands.

- Primary Research Question 1: The Naval System Commands are comprised of the Naval Air Systems Command (NAVAIR), Naval Sea Systems Command (NAVSEA), Naval Supply Systems Command (NAVSUP), Space and Naval Warfare Systems Command (SPAWAR) and Marine Corps Systems Command (MARCORSYSCOM). These are important because they make up most of the commands that have much of the Acquisition Workforce for the Navy. The question this research is to address is what would a systems engineering competency model consist of at the general Naval Systems Commands level to use for SE competency career development, planning and tracking?

## **2. Secondary Research Questions**

While studying the attributes required to create a useful Naval systems engineering competency model, a set of additional secondary research questions surfaced.

- Secondary Research Question 1: What competencies are required for Naval Systems Engineering?
- Secondary Research Question 2: What KSAs are required for systems engineers to develop for naval systems engineering competencies at various career levels?
- Secondary Research Question 3: How does the use of Bloom's Taxonomy for KSA definition relate to competency development along a career path?
- Secondary Research Question 4: Does the COMPOSE model have competencies accurately identified for the KSAs required to be a successful systems engineer?

### **E. PURPOSE/BENEFIT**

The benefit of the research is that it will provide a model, COMPOSE, that can be used by several organizations to identify KSAs pertinent to the development of systems engineers. The COMPOSE model will also allow the DON to formulate competency development plans for the professional development of systems engineers. Finally, the model can contribute to the guidance for development of graduate and undergraduate curricula in systems engineering.

### **F. SCOPE**

The objective of this research is to develop a competency model, and identify and evaluate the cognitive and affective domains associated with SE KSAs. The scope for this project includes defining KSAs using Bloom's Taxonomy Cognitive and Affective Domains, harmonizing the COMPOSE model with Krathwohl's revision of Bloom's Taxonomy, developing an approach and methodology to obtain baseline information needed for the COMPOSE model life cycle development (knowledge, skills, abilities and behaviors, and related education, training, and experience needed), and defining career paths for systems engineers (jobs, assignments, and timing) for the DOD.

## **G. METHODOLOGY**

The team identified eight SE competency models to determine the potential SE competencies for the Navy and organized the elements based on their similarities. The competency models used for the foundation were the SE Workforce Development from the NUWC, INCOSE UK, NASA, DAU SPRDE and Boeing. Each entry from the five competency models were analyzed and re-organized based on the similarity of their competency definitions. Each of the models had different approaches and formats. Some formats combined relevant SE competencies with generic engineering competencies. The KSAs were realigned to fit the COMPOSE model by first eliminating duplication, then eliminating items that didn't seem explicitly defined as a relevant SE competency, re-organizing, and lastly by updating the COMPOSE model to incorporate changes in the 2013 DAU/SPRDE Competency model update. Once the models are harmonized into a single coherent model, it will be analyzed from various perspectives to study the characteristics in order to understand how it would be useful as a baseline model for ultimate use in a future model validation process.

## **H. THESIS STATEMENT**

This study will analyze and determine the KSAs required for DOD systems engineers to be considered competent systems engineers at various levels of career experience levels. Following Bloom's Taxonomy cognitive and affective domain approach provides a comprehensive model. This SE competency model will provide the KSAs that will assist in creating position descriptions and a related SE career development plan designed specifically for systems engineers within the DOD.



Figure 1. Bloom's Taxonomy Domain  
(from Wrightstuffmusic 2014)

## I. REPORT ORGANIZATION

Chapter I comprises the background, research objectives and questions; Chapter II focuses on the analysis portion of this research. Chapter III. reveals the data and methodology behind the analysis. Chapter IV discusses the results of the analysis. Chapter V. shares the conclusions and suggestions for further research efforts.

## J. CHAPTER SUMMARY

This chapter reviewed the evolution of the COMPOSE model by identifying the eight original SE competency models used to create the model. The problem statement was stated, research objectives and research questions were established, the importance of this study was explained and the problem has been examined. To conclude this chapter the scope and methodology were explained and the thesis statement defined. Next is a discussion on the tools used in this analysis to include the literature review and Bloom's Taxonomy.

## II. LITERATURE REVIEW

*The Taxonomy of Educational Objectives is a scheme for classifying educational goals, objectives, and, most recently, standards. It provides an organizational structure that gives a commonly understood meaning to objectives classified in one of its categories, thereby enhancing communication.*

—David Krathwohl  
*A Revision of Bloom's Taxonomy: An Overview*

This chapter will focus on current literature used in the analysis. First is information on Bloom's Taxonomy, including what it is and how it is useful in competency development. Next is a summary of successful competency models.

### A. BLOOM'S TAXONOMY

According to Bloom, skills can be categorized as cognitive, affective, or psychomotor. They are learned and acquired through education training and experience (Bloom, Engelhart, Furst, Hill and Krathwohl 1956). Skills are a composite of abilities, techniques, and knowledge. They are developmental, incremental, and reference-based for a desired application, in this case, systems engineering (Whitcomb, Khan and White 2013).

Benjamin Bloom's system of classification categorizes learning behavior into six levels of cognitive complexity that are cumulative and hierarchical. These levels differentiate three cognitive domains of learning (knowledge, how it is learned), psychomotor (skills, doing, hand/body), and affective (attitudes, feelings, appreciation and value). Each level of the taxonomy is associated with action verbs that can be used to construct learning outcomes and objectives in the cognitive domain. Bloom's Taxonomy was created in 1956 by a group of educational psychologists led by Benjamin Bloom. The goal of the group was to create a foundation for curriculum design and to ensure that educational objectives were being met (Bloom, Engelhart, Furst, Hill and Krathwohl 1956).

The original version of Bloom’s Taxonomy was created more than 50 years ago and many professionals have used it and built upon it effectively. The International Council on Systems Engineering (INCOSE) Graduate Reference Curriculum for SE (GRCSE) used Bloom’s Taxonomy as a foundation with a heavy focus in the cognitive domain and a smaller emphasis on the affective. Krathwohl and Anderson published a revised Bloom’s Taxonomy update in 2001. This updated version resembles the six original; however, “Knowledge” is re-categorized as “Remember,” “Comprehension” is “Understand,” and “Synthesis” is “Create.” Figure 5 illustrates the changes between the 1956 and 2001 versions of Bloom’s.

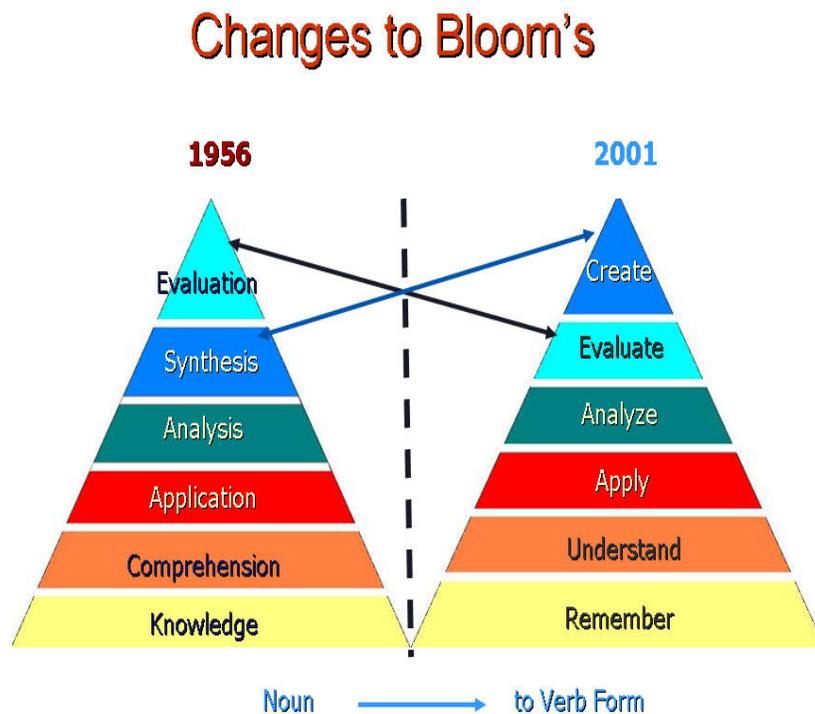


Figure 2. Changes to Bloom’s  
(from Wilson 2013)

Initially, the 1956 version of Bloom’s was used to develop the COMPOSE model because it was used in GRCSE. The COMPOSE model has gone through several iterations. The most current version of the COMPOSE model uses Krathwohl’s revision

of Bloom’s structure. The COMPOSE model only evaluates the cognitive and affective domains. The NPS Team assumed that the psychomotor is not relevant in this study because it does not apply to engineering.

The cognitive domain includes knowledge, critical thinking and the development of intellectual skills. Originally, the categories in the cognitive domain were arranged by order of complexity with the following Bloom’s Levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. Table 2 shows the cognitive domains.

Level	Sub-Level	Competency	Outcome Descriptors
Knowledge	<ul style="list-style-type: none"> <li>• Knowledge of specifics</li> <li>• Knowledge of terminology</li> <li>• Knowledge of specific facts</li> <li>• Knowledge of ways and means of dealing with specifics (processes)</li> <li>• Knowledge of the universals and abstractions</li> </ul>	Ability to remember previously learned material. Test observation and recall of information; i.e., “bring to mind the appropriate information;” e.g., dates, events, places, knowledge of major ideas, and mastery of subject matter.	List, define, tell, describe, identify, show, label, collect, examine, tabulate, quote, and name (who, when, where, etc.).
Comprehension	<ul style="list-style-type: none"> <li>• Translation</li> <li>• Interpretation</li> <li>• Extrapolation</li> </ul>	Ability to understand information and ability to grasp meaning of material presented; e.g., translate knowledge into new context, interpret facts, compare, contrast, order, group, infer causes, predict consequences, etc.	Summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, and extend.
Application	<ul style="list-style-type: none"> <li>• Application of methods and tools</li> <li>• Use of common techniques and best practices</li> </ul>	Ability to use learned material in new and concrete situations; e.g., use information, methods, concepts, and theories to solve problems requiring the skills or knowledge presented.	Apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify,
Analysis	<ul style="list-style-type: none"> <li>• Analysis of elements</li> <li>• Analysis of relationships</li> <li>• Analysis of organizational principles</li> </ul>	Ability to decompose learned material into constituent parts in order to understand structure of the whole. This includes seeing patterns, organization of parts, recognition of hidden meanings, and obviously, identification of parts.	Analyze, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, and infer.
Synthesis	<ul style="list-style-type: none"> <li>• Production of a unique communication</li> <li>• Production of a plan, or proposed set of operations</li> <li>• Derivation of a set of abstract relations</li> </ul>	Ability to put parts together to form a new whole. This involves the use of existing ideas to create new ones, generalizing from facts, relating knowledge from several areas, and predicting and drawing conclusions. It may also involve the adaptation of “general” solution principles to the embodiment of a specific problem.	Combine, integrate, modify, rearrange, substitute, plan, create, design, invent, what-if analysis, compose, formulate, prepare, generalize, and rewrite.
Evaluation	<ul style="list-style-type: none"> <li>• Judgements in terms of internal evidence</li> <li>• Judgments in terms of external criteria</li> </ul>	Ability to pass judgment on value of material within a given context or purpose. This involves making comparisons and discriminating between ideas, assessing the value of theories, making choices based on reasoned arguments, verifying the value of evidence, and recognizing subjectivity.	award, choose, conclude, criticize, decide, defend, determine, dispute, evaluate, judge, justify, measure, compare, mark, rate, recommend, rule on, select, agree, interpret, explain, appraise, prioritize, opinion,

Table 1. Bloom’s Taxonomy of Educational Outcomes—Cognitive Domain (from GRCSE 2011, 97–98)

The affective domain has to do with emotions, feelings and attitudes. Objectives describe growth in awareness, attitude, emotion, changes in interest, judgment and the development of appreciation. Table 3 shows the affective domains. While most educators do not include the affective domain in their curriculum, in fact this domain is completely absent from the DAU SPRDE curriculum, these outcomes are especially critical to the success of systems engineers because it is also important to communicate well and work cohesively as part of a team (Hudson 2013).

Level	Sub-Level	Competency	Outcome Descriptors
Receiving	<ul style="list-style-type: none"> <li>• Awareness</li> <li>• Willingness to receive</li> <li>• Controlled or selected attention</li> </ul>	The learner is aware of stimuli and is willing to attend to them. The learner may be able to control attention to the stimuli.	Focuses on and is aware of aesthetics, focuses on human values, is alert to desirable qualities, and shows careful attendance to input.
Responding	<ul style="list-style-type: none"> <li>• Acquiescence in responding</li> <li>• Willingness to respond</li> <li>• Satisfaction in response</li> </ul>	The learner makes a conscious response to the stimuli related to the aesthetic or quality. At this level the learner expresses an interest in the aesthetic things.	Demonstrates willing compliance and obedience to regulations and rules, seeks broad-based information to act upon, and accepts responsibility and expresses pleasure for own situation.
Valuing	<ul style="list-style-type: none"> <li>• Acceptance of a value</li> <li>• Preference for a value</li> <li>• Commitment</li> </ul>	The learner recognizes worth in the subject matter.	Continuing desire to achieve, assumes responsibility for, seeks to form a view on controversial matters, devotion to principles, and faith in effectiveness of reason.
Organization	<ul style="list-style-type: none"> <li>• Conceptualization of a value</li> <li>• Organization of a value system</li> </ul>	The learner is able to organize a number of values into a system of values and can determine the inter-relationships of the values.	Identifies characteristics of an aesthetic, forms value-based judgments, and weighs alternative policies.
Characterization	<ul style="list-style-type: none"> <li>• Generalized set</li> <li>• Characterization</li> </ul>	The learner acts consistently with the systems of attitudes and values they have developed. The values and views are integrated into a coherent worldview.	Readiness to revise judgment in light of evidence, judges problems and issues on their merit (not recited positions), and develops a consistent philosophy of life.

Table 2. Bloom’s Taxonomy of Educational Outcomes—Affective Domain (from GRCSE 2011, 99–100)

Systems engineers lead systems projects, negotiate outcomes with a diverse group of stakeholders, make value judgments and must have the ability to deliberately take the systems perspective (GRCSE, 2011, p. 95). Leading, negotiating, and having sound

judgment are all affective outcomes. Almost 29 percent of the COMPOSE model’s KSAs fall into the affective domain which indicates how important both technical/technical management and professional skills are in becoming a successful systems engineer. The five levels of the affective domain are arranged by order of complexity as follows: receiving, responding, valuing, organization and characterization. Table 3 shows the affective domains. The cognitive and affective skills are mapped to proficiencies within the competencies based on the key words used which correlate to a specific cognitive or affective category. For example, if a KSA says “Analyze sponsor/customer information for the development of acquisition plans” The verb “analyze” corresponds to the higher-level cognitive domain as shown in Tables 2-3.

The current version of the COMPOSE model uses Krathwohl’s version of Bloom’s Taxonomy. Krathwohl converts the category from a noun to a verb. For example within the cognitive domain there was originally “Evaluation”, in Krathwohl’s version it is “Evaluate”. Figure 6 shows Krathwohl’s Bloom’s Taxonomy Update. Analysis reveals that about 67 percent of the COMPOSE model’s KSAs fall into the cognitive domain and 33 percent are aligned with the affective domain (Whitcomb, Khan and White 2013).

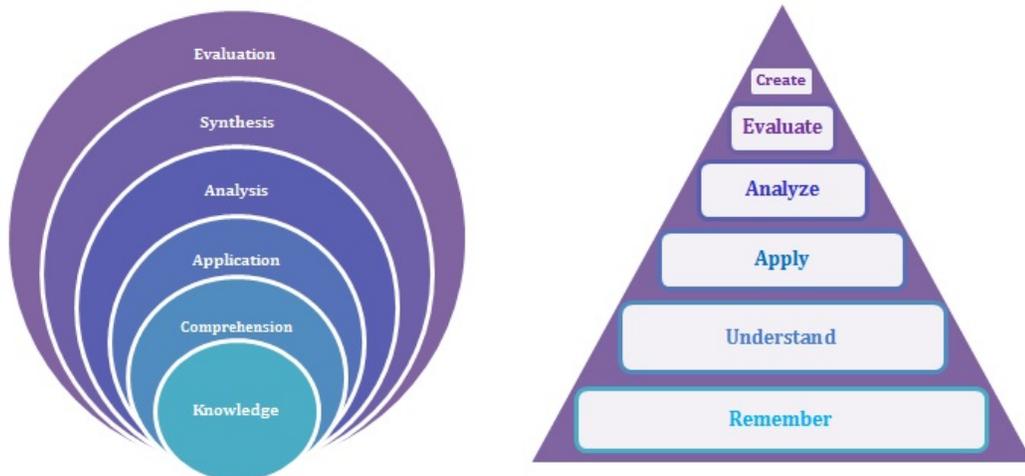


Figure 3. Krathwohl’s Bloom’s Taxonomy Update—Cognitive Domain (from Florida International University 2014)

## **B. SUCCESSFUL COMPETENCY MODELING APPROACHES**

Prior to developing COMPOSE, several competency model approaches were explored, such as The Pragmatic Guide to Competency report by Holt and Perry, The Career and Competency Pathing report by LaRocca, the GRCSE report by INCOSE and The U.S. Department of Labor Employment and Training Administration (ETA) User Guide to Competency models. The COMPOSE model was developed with all of these aspects in mind (Alexander 2013).

The Holt and Perry Guide focuses on what defining a good competency model. As discussed in Chapter I, this guide concludes that a good competency model goes through many iterations, focuses on a specific aspect of competency but is easy to understand, maps competencies across levels, keeps a small number of levels, maps levels clearly and emphasizes technical skills (Holt and Perry 2011).

Successful competency models also serve as a platform by which individuals can assess their skill set. Although, not in the scope of this research, in the future the COMPOSE model will be used in efforts to assess individual's skills. An example of this, following the Body of Knowledge model established by the Association of Project Management (APM), is to apply a rating (which may be 1, 2, 3, or 5 –no. 4) that provides a weight for making the calculation to derive a point value, by which an individual can assess how competent he or she is in an activity. To do so, an individual can determine how valuable certain information on a learned activity has been by defining the value on a scale of 2 to 10, where “2” is considered of “little value” and “10” is considered to be of “high” value. The individual would then multiply the rating and the value together to attain a “point value” – which can then be assessed to determine evidence of competency. Although out of scope for this research effort, it should be stressed that along with having an assessment procedure in a competency model, the competency model should also include a framework for validating assessments.

The *Career and Competency Pathing Competency Modeling Approach* by LaRocca concentrates on how organizations can identify their core competencies and how they can apply the competency data to improve performance. Additionally, it explains some emerging trends in competency modeling. According to LaRocca, it is imperative that organizations understand what knowledge, skills and abilities are required

for people in key roles to deliver business goals. LaRocca also stresses there are six stages in defining a competency model for a given job role which include the following: defining the criteria for superior performance in a given role, choosing a sample of people performing the role for data collection, collecting sample data about behaviors that lead to success, developing hypotheses about the competencies of outstanding performers and how competencies work together to produce desired results, validating results of data collection and analysis and applying the competency models in real case scenarios (LaRocca n.d.).

Key findings from the Schoonover Associates and Arthur Anderson 2002 study determining how organizations actually use competency data to be successful in real-life applications were also highlighted (Boulter, Dalziel and Hill 1998). Of these, it was noted that the use of competencies, in order of their effectiveness, includes hiring, job descriptions, training, performance management, and development planning and career pathing. (Shoonover, Shoonover, Nemerov and Ehly 2012). While not in the scope of this research, it would be interesting to analyze exactly how the COMPOSE model was used in a given organization after being adopted. For example, what percentage of the model was used to create job descriptions, initiate training requirements?

GRCSE is a part of the Body of Knowledge and Curriculum to Advance System Engineering (BKCASE) (INCOSE n.d.). This approach keys in on how to use Bloom's Taxonomy to set the level of attainment of educational or learning outcomes required for students engaged in an educational unit, course or program. In GRCSE, the major focus is on the cognitive domain, which is concerned with knowledge and how it is learned (Huitt n.d.). The affective domain is a minor focus, as it is concerned with feelings, appreciation and valuation of the content that is learned. In some education, for example military and theological, the affective domain is an explicit focus of the outcomes because of the high standard of morals and values emphasized. This is why in this study focuses on both the cognitive and affective domains.

The U.S. Department of Labor, Employment and Training Administration (ETA) User Guide to Competency Model (U.S. Department of Labor Employment and Training Administration 2013) shows five steps to developing a competency model as shown in Figure 7.

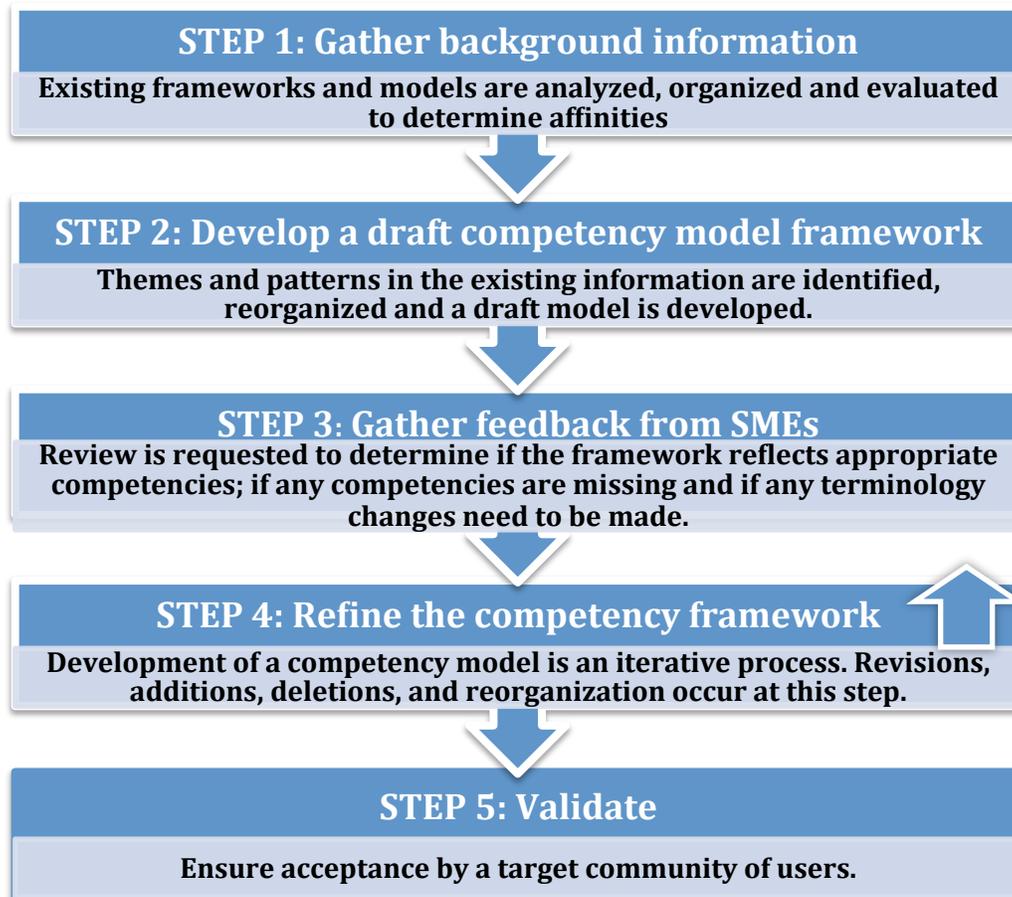


Figure 4. Competency Model Development Steps (from U.S. Department of Labor Employment and Training Administration 2013)

Note that steps 3 and 4 are repeated until the subject matter experts (SMEs) and the development team agrees that the model is an all-inclusive representation of required KSAs.

**C. EXISTING SE COMPETENCIES SERVE AS A FOUNDATION**

*The last thing that the world needs is yet more frameworks, so, again, the idea of cherry-picking different parts from different frameworks is a very attractive one.*

—John Holt and Simon A. Perry  
*A Pragmatic Guide to Competency: Tools, Frameworks and Assessment*

Several competency models were used to construct the COMPOSE model including NUWC, INCOSE UK, NAVAIR, SPAWAR, Boeing, NASA, MITRE and SPRDE. Collectively, these competency models created the forty-one competencies in the COMPOSE model. Figure 8.0 is an illustration of how existing competency models were used to create the COMPOSE model.

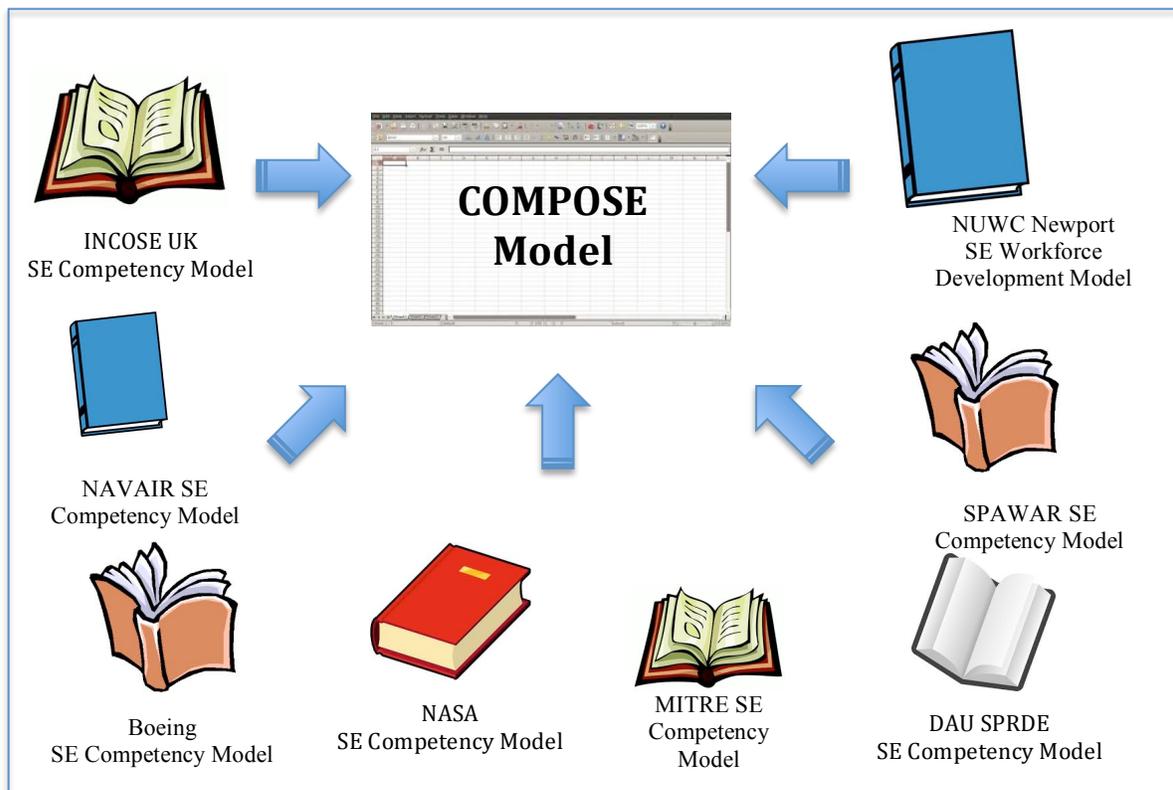


Figure 5. Competency Sources Used in COMPOSE  
( from Whitcomb, Khan and White 2013)

All of the models introduced were used as a foundation to identify competencies to map to the 41 competencies for the COMPOSE model. The next step in developing the COMPOSE model was to identify KSAs and map them to the 41 competencies. However, only three of these models NUWC, INCOSE UK and MITRE were used to derive the KSAs for the COMPOSE model based on their format and range of KSAs for SE. Additionally, the DAU SPRDE Level I, II, and III course learning objectives were

transformed into KSAs and added to the model. Figure 9 shows the models used to derive the KSAs. The Overall COMPOSE model v0.78 has 2,914 KSAs.

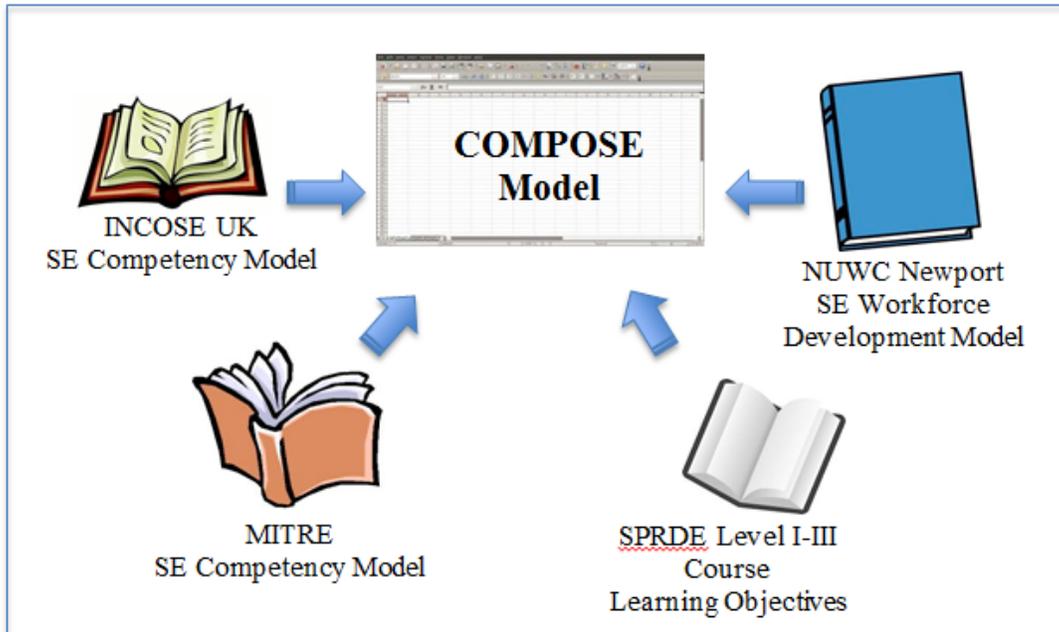


Figure 6. KSAs sources used in COMPOSE  
(from Whitcomb, Khan and White 2013)

**1. SE Workforce Development Naval Underwater Warfare Center Competency Model**

The purpose of the Naval Underwater Warfare Center (NUWC) SE workforce competency model is to articulate clearly and establish the development of the NUWC SE workforce. With twenty-eight competencies, six experience levels and 689 KSAs, this competency model displays a series of steps that are used in sequence to derive requirements and then transform those into solutions. The model is written in such a manner that it is intended to be used without the size or complexity of the problem being an issue (Walter 2013). The goal for the NUWC competency model is to provide a tool for the SE Workforce that will serve as a guide to ensure that the program execution is right from the beginning and that problems are addressed early. If used correctly, it could aid in minimizing risk and reducing costs. The model clearly identifies the KSAs,

behaviors, attitudes, attributes and performance expected of a SE at specified career experience levels. However, there is no explanation of where or how these KSAs can be obtained if a SE is lacking those KSAs.

## **2. International Council on Systems Engineering United Kingdom Competency Model**

This system engineering competency model was developed by a working group of SE representatives from over 10 different organizations. It is a framework for generic purpose and organized in a way that is easy to tailor for specific purposes. The model's foundation is built on official system engineering standards, and it focuses primarily on technical SE competencies, while making it evident that when linked with processes, organizations and infrastructure then capabilities are created. This model is composed of 21 competencies, four experience levels and 273 KSAs. Similar to other SE Competency models, the International Council on Systems Engineering (INCOSE) model identifies key competencies in SE, introduces supporting techniques, identifies basic skills and behaviors and describes the domain knowledge required (UK, INCOSE).

## **3. MITRE Competency Model**

Similar to the COMPOSE model's methodology, the MITRE Competency model takes a government view and approach to systems engineering. This comprehensive model identifies all of the competencies needed to fulfill a particular role in the SE process; for example, Systems Engineering Planning (Transformational Planning, Government Acquisition Support, Contractor Evaluation, Risk Management, Configuration Management, Integrated Logistics Support, Q&A Measurement and Continuous Process Improvement) and the Management of Systems Engineering Life Cycle (Concept of Operation, Requirements, Architecture, System Design, Systems Integration, Test and Evaluation, Systems Implementation, O&M and Transition) are examples of the competencies MITRE identified that fulfill a specific role in the SE process. This approach to competency modeling is more useful in developing individuals and teams for a wide range of system engineering jobs. The non-technical competencies

were extracted from the MITRE Institute Leadership and Management Competency models. The model is composed of forty-one competencies and 1,262 KSAs.

#### **4. Defense Acquisition University System Planning, Research, Development and Engineering Learning Objectives**

Using a competency-based model, Defense Acquisition University (DAU) used Bloom's taxonomy to provide the framework for course development (Layton 2007). Level I certifications were structured to reflect basic knowledge, Level II built on that basic knowledge introducing practical application and small group scenarios, and Level III certifications were to develop synthesis and evaluation abilities. The 112 course learning/ performance objectives (CL/PO) and 542 educational learning objectives (ELO) were categorized according to the Graduate Reference Curriculum for Systems Engineering (GRCSE) version of Bloom's Taxonomy. None of the data fell into the affective domain; hence, all CL/POs and ELOs were categorized into the cognitive domain as knowledge, comprehension, application, analysis, synthesis or evaluation.

#### **D. CHAPTER SUMMARY**

This chapter discussed in detail all of the frameworks that contributed to the creation of the COMPOSE model. Six references and eight competency models were used to investigate Bloom's taxonomy, competency model definitions, and the application of the competency models for this research. Bloom's Taxonomy was used to categorize each KSAs into the cognitive and affective domain. NUWC, INCOSE UK, NAVAIR, SPAWAR, NASA, MITRE, SPRDE and Boeing competency models serve as the foundation for the COMPOSE model.

### **III. COMPETENCY MODEL DEVELOPMENT**

Chapter II provided more information on how Bloom's Taxonomy is useful in competency development and summarize the existing competency models that were chosen to be the foundation for the COMPOSE model. This chapter will discuss in detail how the COMPOSE model evolved. One of the goals of the NPS team was to have a model that could go through several updates and changes; therefore, the NPS Team dedicated a tremendous amount of effort on aligning information from the existing competency models to fit the COMPOSE model, eliminating data that are not useful, incorporating the DAU SPRDE CL/POs and ELOs and identifying training levels. KSAs were mapped to fit GRCSE Bloom's Taxonomy in the first version of the COMPOSE model. In the most current version of the COMPOSE model KSAs are mapped to Krathwohl's revised version of Bloom's Taxonomy.

The COMPOSE model contains an aggregate of the core technical/technical management and professional KSAs researched from existing competency models from various naval engineering enterprises. The KSAs described in the COMPOSE model are those that are vital for the development of proficient systems engineers. The COMPOSE model provides a basis for a single, coherent SE competency model that will assist in creating position descriptions and a related SE career development plan designed specifically for systems engineers within the DON, and to provide a basis for a model for DOD. Table 1 identifies the attributes of the COMPOSE model and compares them to what the Pragmatic Guide to Competency states a good competency model should contain.

The COMPOSE model was envisioned to focus on the specific competencies that define systems engineers on a primarily technical and technical management basis; for example, Mission-Level Assessment, Requirements Analysis, or Architecture Design are all technical and technical management competencies. The COMPOSE model also includes generic engineering professional skills; such as Coaching and Mentoring, Communication, and Personal Effectiveness/Peer Interaction.

Appendix A shows an example of the competencies mapped across experience and proficiency levels. The tables also show the proficiency levels within each competency based on the analysis. The team categorized KSAs in the form of Bloom’s Taxonomy, primarily into either the cognitive or affective domain, for each KSAs for core (technical) SE competencies to determine the proficiency levels within the SE career development levels.

The COMPOSE model can be used to tailor sets of KSAs desired to develop competent system engineers for any DON organization. The model is also intended to be used by universities and training organizations to inform their development of learning objectives to meet the appropriate competency attainment for various SE positions. Additionally, the model should be useful as a foundation for defining systems engineering professional certification.

Attributes of a Good Competency Model	Model Meets Requirement (Y/N)	POA
1. Many Iterations	Y	
2. Simple and easy to understand	Y	
3. Maps levels in a non-complex format	Y	
4. Emphasizes technical skills versus soft skills	N	NPS Team is currently looking at the leadership, problem solving, professional ethics, interpersonal and personal skills, strategic thinking and communications separately to determine whether there are any key "soft" competencies systems engineers should exhibit.
5. Provides an assessment procedure and a framework for validating assessments	N	For Future Research. Plan to work with OPM to validate the model.
6. Combines skills from different models to generate a complete scope of competencies required for a systems engineer	Y	

Key:  
 SE- Systems Engineering  
 Y/N – Yes or No  
 POA – Plan of Action

Table 3. COMPOSE Attributes (Adapted from Holt and Perry 2011)

## 1. Evolution of the COMPOSE Model

There is consensus between the Naval Postgraduate School (NPS) systems engineering (SE) research team and the Deputy Assistant Secretary of the Navy (DASN), Research, Development, Test and Evaluation (RDT&E), Chief Engineer (CHENG) that the required competencies and certifications for proficient DON systems engineers need to be examined (Whitcomb, Khan and White 2013). The DASN (RDT&E) desires a concrete study of what systems *engineers* do and how they develop throughout their careers. As part of a DASN (RDT&E) strategic initiative, a team from NPS's Systems Engineering Department developed an overall approach in order to design a naval systems engineering competency model, ultimately named COMPOSE

The NPS model began with the identification of eight previously existing SE competency models.

- NUWC
- INCOSE UK
- MITRE
- NASA
- NAVAIR
- SPAWAR
- DAU SPRDE
- Boeing

Each of the SE competency models used is described in more detail in Chapter II. Elements of these eight models were categorized based on similarity, with their competencies mapped to the original 29 DAU/SPRDE competencies and duplicate elements were eliminated. The COMPOSE model used several other SE competency models as a foundation to get a broad perspective of the KSAs required to be a competent SE. The COMPOSE model also includes the DAU SPRDE-SE learning objectives, the degree to which the learning objectives reflect actual competencies needed to perform as an acquisition systems engineer, the impact they have or potentially have on SPRDE acquisition workforce members, and how various members fit into the current DAU certification structure.

Skills, abilities, and behaviors, were combined with knowledge to form the basis for determining how well someone can perform as a systems engineer (Whitcomb, Khan and White). Three of the eight SE development models were used to assist in determining KSAs required across different SE career experience levels. The SE development models used are as follows: INCOSE UK, MITRE, and the SE Workforce Development NUWC. Each competency model used had various career levels of experience based on their organizational structure. Bloom's Taxonomic data is used to map these KSAs into three Naval SE experience levels and domains based on the following experience level definitions:

#### **SE-01 Entry Level (0–3 years of work experience)**

- Able to understand the key issues and their implications. They are able to ask relevant and constructive questions on the subject. This level requires an understanding of the Systems Engineering role within the enterprise.
- *Example: New hires enrolled in an engineering career development program, typically able to complete it in 3 years.*

#### **SE-02 Journey Level (3–10 years of work experience)**

- Displays an understanding of the subject but may require minimal guidance and with proper training and opportunity will be able to provide guidance and advice to others.
- *Example: GS-12 engineers who are working in systems engineering.*

#### **SE-03 Expert Level (10–12+ years of work experience)**

- Contains extensive and substantial practical experience and applied knowledge of the subject.
- *Example: Senior systems engineers who are leading systems engineering teams and possibly act as a chief system engineer.*

The NPS team decided to address the mapping of these competencies across proficiency levels in an effort to create a foundation for SE career development within the

DON. Each of the KSAs was mapped to one of three specific career levels designated as SE-01 Entry Level, SE-02 Journey Level or SE-03 Expert Level as shown in Figure 7.

## COMPOSE Structure

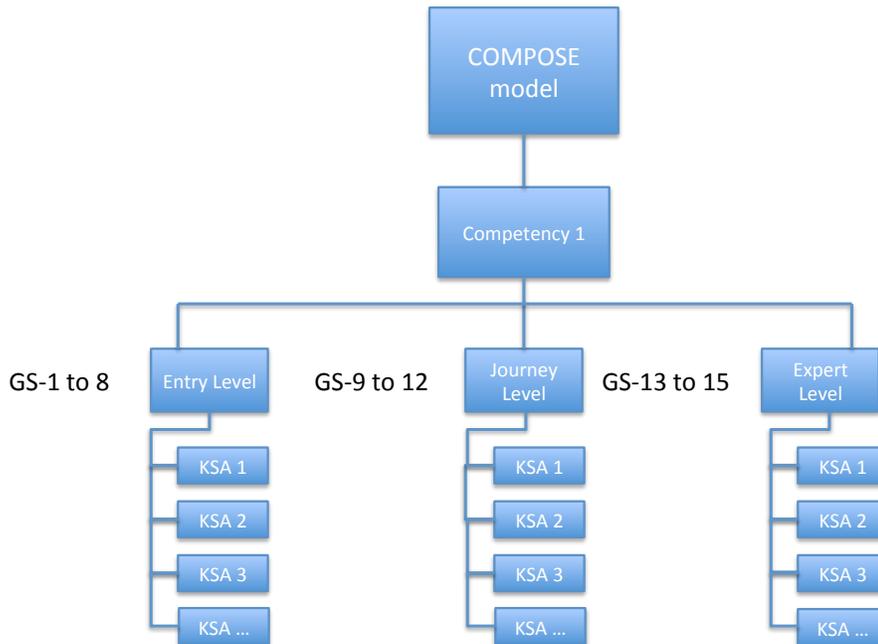


Figure 7. COMPOSE Career Development Levels

This was accomplished by first defining each of the KSAs according to Bloom's Taxonomy of Educational Objectives, which is discussed in more detail later in this section. Specifically, the NPS team used the version of Bloom's Taxonomy by Krathwohl as shown in Figure 8. This rating and mapping further strengthened the COMPOSE model with the inclusion of yet another valid information source.

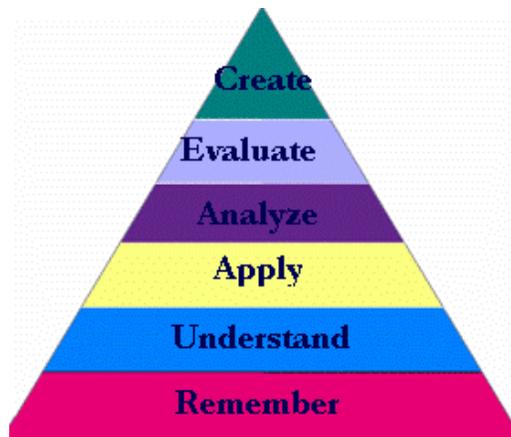


Figure 8. Krathwohl's Bloom's Taxonomy  
(from MMI n.d.)

Bloom's Taxonomy for the Cognitive Domain provides hierarchical outcome categories or levels that range from simple to complex thought processes. Once the Bloom's level for each of the KSAs was identified, the KSAs in each competency were divided into the three career levels by assigning the KSAs with lower Bloom's level ratings to the SE-01 Entry Level, the KSAs with intermediate Bloom's level ratings to SE-02 Journey Level and the KSAs with higher Bloom's level ratings to the SE-03 Expert Level. Finally, the potential sources of the learning are partitioned into categories where the most appropriate learning and assessment can take place. Training is focused on learning that is applied to the narrow context in which the task is accomplished. Education is broader and focuses learning on concepts and not as much in the concrete accomplishment of specific tasks. The tasks in education are "authentic" at best, covering learning that can be transferred into many different contexts. On the job experience is very specific to the accomplishment of a task within a specific way that an organization desires it to be completed in a "real" situation. Professional development is targeted at learning opportunities that are education and training based. However, professional development has a narrow scope in the context of the specific development within a community of practice. An example of this model showing Competency 11.0 Tools and Techniques is illustrated in Appendix B; it is also shown in Figure 9.

<b>Knowledge Skills &amp; Abilities (KSAs)</b>			
<b>Cognitive &amp; Affective Skill Levels</b>	<b>Education</b>	<b>Training</b>	<b>On the Job Experience</b>
<b>Remember, Understand, Receive Phenomena &amp; Respond to Phenomena</b>			
Understand the scope and limitations of models and simulations, including definition, implementation and analysis	x		
Understand the need for system representations	x		
Understand the different types of modeling and simulation	x		
Support the M&S specialist in creating and validating models			x
Support systems studies and analyses			x
Participate in networked and federated M&S developments (e.g., training exercise support or simulation war games), with assistance from the specialist		x	
Know which models, simulations, or decision support tools can be used to support your analysis, evaluation, instruction, training or experiment	x		
Know various models & simulations and when it is beneficial to integrate them	x		
Know the right model or simulation to meet your specific needs	x		
Know decision support tools, models, or simulations that are applicable to your job	x		
Collaborate with the specialist to run M&S scenarios, based on current and future operational capabilities			x
Assist the specialist with collecting data and formulating assumptions to create and validate simple simulation models (e.g., operational capabilities, networking, computing resources, and processes)			x
<b>Apply, Analyze, &amp; Value</b>			
Demonstrate candidate modeling and/or simulation approach (e.g., constructive, virtual, and live synthetic environments) while working with the specialist			x
Build prototypes or design experiments to test system concepts and their feasibility	x		
<b>Evaluate, Create, Organize &amp; Characterize by a Value</b>			
Survey existing data and previous modeling efforts to incorporate previous M&S capabilities into the current effort			x
Identify potential integration and interoperability links within and between modeling and simulation tools and synthetic environments		x	

Figure 9. The COMPOSE Model Education, Training and On the Job Experience for Competency 11.0 Tools & Techniques Entry Career Level Example

The third iteration of the COMPOSE model verification was initiated by research to analyze and to determine to what extent the DAU SPRDE-SE certification curriculum provides the basis for defining KSAs to support the development for DOD systems engineers. As an initial part of the analysis, 654 Course Learning/ Performance Objectives (CL/PO) and Enabling Learning Objects (ELO) for seven DAU SPRDE-SE Level III required courses were identified. These CL/POs and ELOs were written in a format similar to format of the KSAs in the COMPOSE model. The NPS Team defined the CL/POs and ELOs as KSAs and added them to the COMPOSE model. They were also mapped to competencies in the COMPOSE model and to the Graduate Resource

Curriculum for Systems Engineering The Graduate Reference Curriculum for SE (GRCSE) Bloom's levels. (Alexander 2013).

The COMPOSE model was used by SPAWAR Systems Center (SSC) Atlantic as a foundation to develop their systems engineering competency model. Since SPAWAR is part of the DON, this shows that the COMPOSE model is useful as intended for tailoring to specific implementations. SPAWAR being able to use the COMPOSE model is verification that organizations within the DOD can use the COMPOSE model by tailoring to meet the organization's goals. In the SPAWAR example, the KSAs and categorization will help determine exactly how education and training (structured and unstructured) can best be utilized to maximize the effectiveness of systems engineers (Walter 2013).

The SPRDE Career Development model was changed to the ENG Career Development model in September 2013 (Kendall 2013). The fourth and most recent update of the COMPOSE model was initiated when the 2013 ENG Competency Update was released. This refresh added KSAs and required a revision of the KSA nomenclature in the COMPOSE model. As a result of this update the COMPOSE model has a total of 41 competencies and 2,914 KSAs.

## **B. ALIGNING INFORMATION GATHERED**

Within the eight original competency models used as a foundation to create the COMPOSE model, competency KSA statements were not defined in a consistent way. Some models had overlap, for example, "Able to guide a new practitioner" is a KSA that was originally aligned with eight competencies, technical planning, acquisition, integration, validation, transition, verification, architecture design and systems engineering leadership. The NPS approach was that KSA should occur in only one competency, and for this this KSA should only be aligned to one called "Coaching and Mentoring" similar to the SPRDE competency model approach. Some models had more competencies than others. All of the competency models were initially re-categorized based on the DAU SE Competency model of forty-one competencies in an effort to tailor the model specifically to DOD. Although each of the reference competency models had

similar purposes, each was tailored to the individual organization. This tailoring resulted in several different formatting styles to include Microsoft (MS) Excel tables, Adobe reports and MS PowerPoint presentations. This tailoring also resulted in some of the models using electronic format while others were in the paper format. These differences in format and formatting styles required steps to harmonize the final model.

The first step was to identify the format that would best fit the COMPOSE model. When determining the best format, it was important to think about who would be using the model and the best format for them. It was also equally important to ensure that the format of the model could accommodate several updates and changes. It was determined to initially use an Excel spreadsheet model that could be provided to any organization to use or to alter the model to easily meet their organizational needs. This spreadsheet could also handle several iterations and is useful for making updates to and changing the model to meet specific needs. Based on input, it was also decided to use a report format that would incorporate tables automatically generated in the Excel spreadsheet. These tables could easily be incorporated into a more formal Competency Report output.

The spreadsheet was organized in columns. The column headings include the COMPOSE model Competency, KSAs, Bloom's Cognitive, Bloom's Affective, Proficiency Level and Experience Level. Each KSAs was entered into an individual row and filled out appropriately. The spreadsheet has the ability to filter on any competency, KSAs and proficiency level.

COMPOSE Competen	COMPOSE KSA	COMPOSE Category	COMPOSE Experience Le	Krathwohl 2002_Cogniti	Affective	Cognitive & Affective Domains (Krathwohl 2002)	Source
21.0 ACQUISITION	Analyze sponsor/customer information for the development of acquisition plans.	Technical & Technical Management	SE-1 ENTRY LEVEL		Respond (RS)	Remember, Understand, Receive Phenomena & Respond to Phenomena	On the Job Experience
21.0 ACQUISITION	Analyze the impact of supportability issues on system readiness/performance and other functional areas. E.g. contracts, finance, systems engineering and acquisition logistics	Technical & Technical Management	SE-2 JOURNEY LEVEL	Analyze (AN)		Apply, Analyze, & Value	Training
21.0 ACQUISITION	Analyzes trade-offs during implementation involving design constraints, budget, schedule, and changing priorities across projects and programs.	Technical & Technical Management	SE-2 JOURNEY LEVEL	Analyze (AN)		Apply, Analyze, & Value	Education

Figure 10. COMPOSE Model V0.78

### **C. SCREENING**

Now that all of the data was in the same format, the next step was to eliminate duplication and items that do not fit. Unique identifiers were given to each of the KSAs rows. If any of the deleted KSAs need to be used in the future, they can be restored by using the assigned unique identifier to trace it back to the original source of the KSAs.

The spreadsheet version of the COMPOSE model that is available to organizations is a cleaned up version with only the fields that are required to create a competency model. Additionally, NPS has the original “in-house” COMPOSE that has other fields like the original competency model source, original KSAs and experience level.

### **D. INCORPORATING DAU SPRDE CL/POS & ELOS**

A total of 654 course learning/ performance objectives (CL/POs) and enabling learning objects (ELOS) for seven DAU SPRDE-SE Level III required courses were identified. These CL/POs and ELOS were then defined as KSAs and added to the COMPOSE model. These DAU/SPRDE KSAs were also mapped to competencies in the COMPOSE model and to the GRCSE Bloom’s levels (Alexander 2013).

Incorporation of the DAU CL/POs and ELOS into the NPS SE competency model required considerable manipulation. First, the new KSAs were reworded to incorporate the same Bloom’s verbs that are used in the rest of the COMPOSE model. Six duplicates were discovered and discarded. A total of 607 DAU KSAs were ultimately added to version 0.5 of the COMPOSE model. Figure 11 shows how the DAU CL/POs and ELOS were incorporated into the model (Alexander 2013).

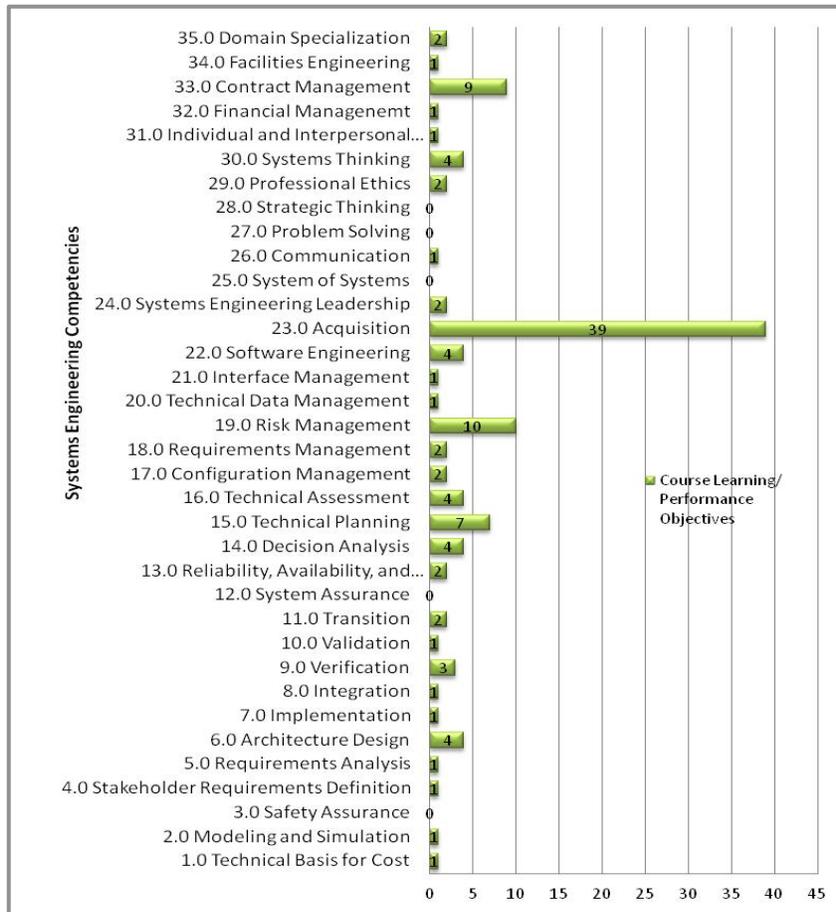


Figure 11. Number of DAU SPRDE-SE CL/POs in each System Engineering Competency (from Alexander 2013)

The most recent version 0.78 of the COMPOSE model incorporates all of the changes. Analysis of the KSAs shows that 23 percent of the KSAs within the COMPOSE model are derived directly from the ENG Competency model as shown in Figure 12. The spread of KSAs across career levels is shown in Figure 13. By inspection, the number of KSAs in the COMPOSE model that were originally from the ENG Competency model in each career level seem to be consistent.

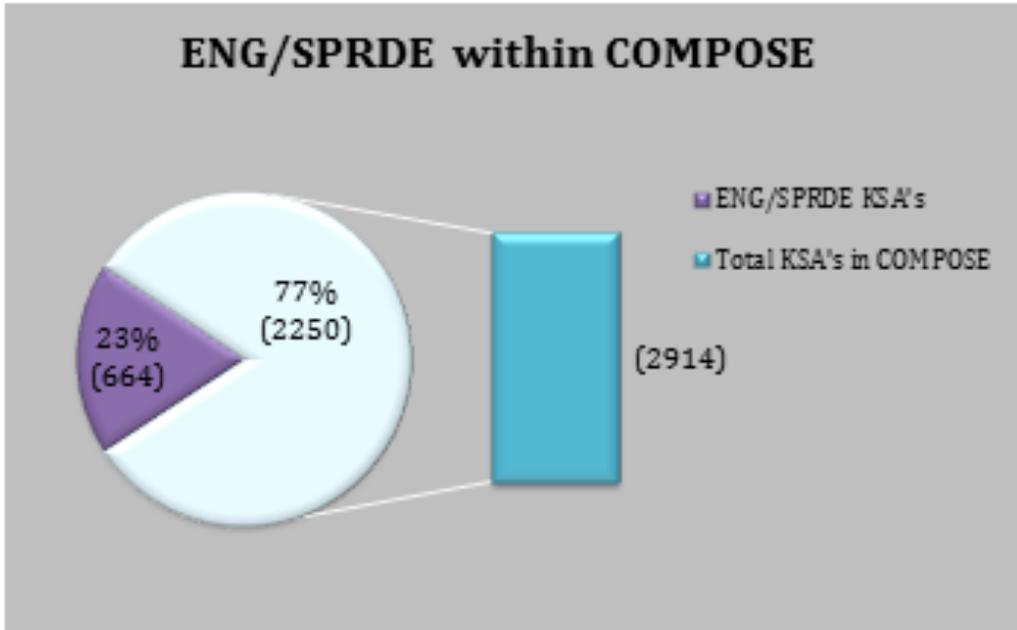


Figure 12. ENG KSA's within COMPOSE V0.78

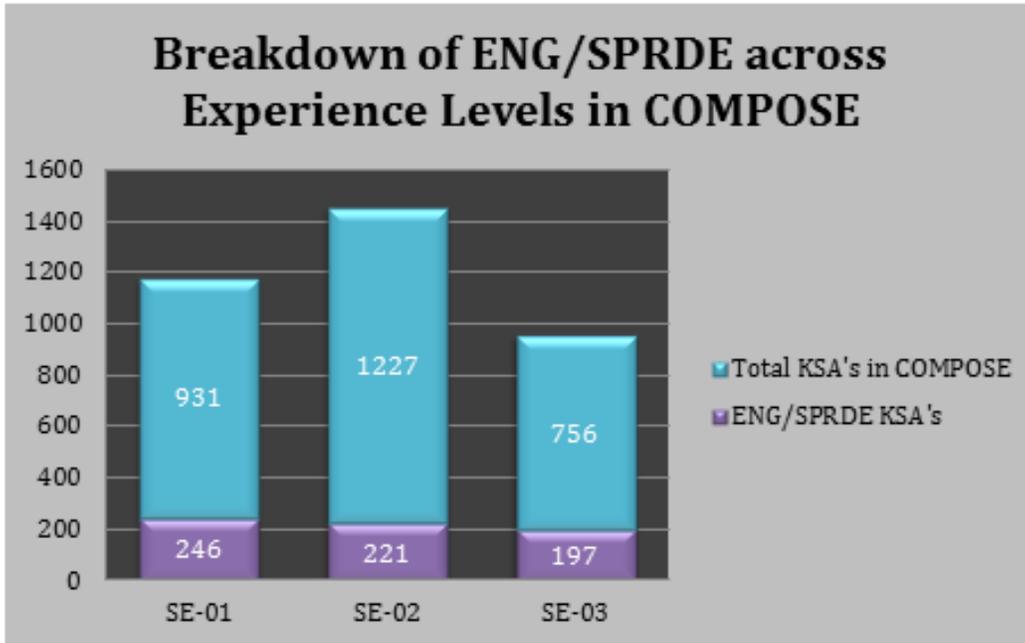


Figure 13. Breakdown of ENG KSA's across experience levels in the COMPOSE model V0.78

## **E. MAPPING TO FIT BLOOM'S TAXONOMY**

Each KSAs was mapped according to Bloom's Taxonomy of Educational Objectives. There are several interpretations of Bloom's; however, Krathwohl's version of Bloom's Taxonomy, which is shown in Chapter I, was used for the mapping. As discussed in Chapter II, only the cognitive and affective domains were used for analysis in the COMPOSE model. The NPS Team assumed that the psychomotor is not relevant in this study because it does not apply to engineering in any useful way.

## **F. IDENTIFYING CAREER LEVELS**

To address the application of these competencies across proficiency levels, each of the KSAs was mapped to one of three specific career levels designated as SE-1 Entry Level, SE-2 Journey Level or SE-3 Expert Level. Bloom's Taxonomy provides hierarchical outcome categories or levels that range from simple to complex thought processes. Once the Bloom's level for each KSAs was identified, the KSAs in each competency were divided into the three career levels by assigning the KSAs with lower Bloom's level ratings to the SE-1 Entry Level, the KSAs with intermediate Bloom's level ratings to SE-2 Journey Level and the KSAs with higher Bloom's level ratings to the SE-3 Expert Level. This is just a starting point, as the assignment of various KSAs to different Bloom's levels will be conducted by any organization in their implementation.

## **G. IDENTIFYING POTENTIAL COMPETENCY LEARNING SOURCES**

The competencies were categorized as to whether they would be developed by "Education", "Training," and "On the Job Experience". An example of this model showing Competency 11.0 Tools and Techniques is illustrated in Appendix A. This step was important in the analysis because it would provide an initial mapping to assist organizations in designing SE career development plans and provide undergraduate and graduate SE programs a baseline that identifies the KSAs employers expect SE to have obtained from their various education and training programs, including undergraduate and graduate education. This information could be used to ensure SE educational programs learning objectives meet the requirements of the workforce or the "customer".

## **H. COMPETENCY SUMMARY**

The COMPOSE model V0.78 includes all of the competencies, both technical and professional were left in the model in an effort to make it easier for an organization to tailor the model to meet its needs. Future naval system command SME ranking of importance in a follow on research project will further determine what KSAs should be in the final model.

## **I. CHAPTER SUMMARY**

This chapter presented a detailed description of how the COMPOSE model was developed, the foundational framework used and how the original information gathered was aligned. The information from the eight reference competency models was combined based on similarities, un-useful data was eliminated, DAU SPRDE CL/POs and ELOs were incorporated, training levels were identified and KSAs were mapped to fit Bloom's Taxonomy. Currently, the COMPOSE model has 41 competencies, 2,914 KSAs and three notional skill levels. The next chapter will analyze the findings.

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## IV. DATA AND ANALYSIS

This chapter discusses some trends and findings identified when analyzing both the technical and professional portions of the COMPOSE model. This chapter will also discuss the differences and similarities between the cognitive and affective levels.

### A. PRIMARY RESEARCH: COMPOSE V0.78 DATA

When analyzing the COMPOSE model, 67% of the KSAs were aligned with the cognitive domain while 33% were aligned with the affective domain as shown in Figure 14.

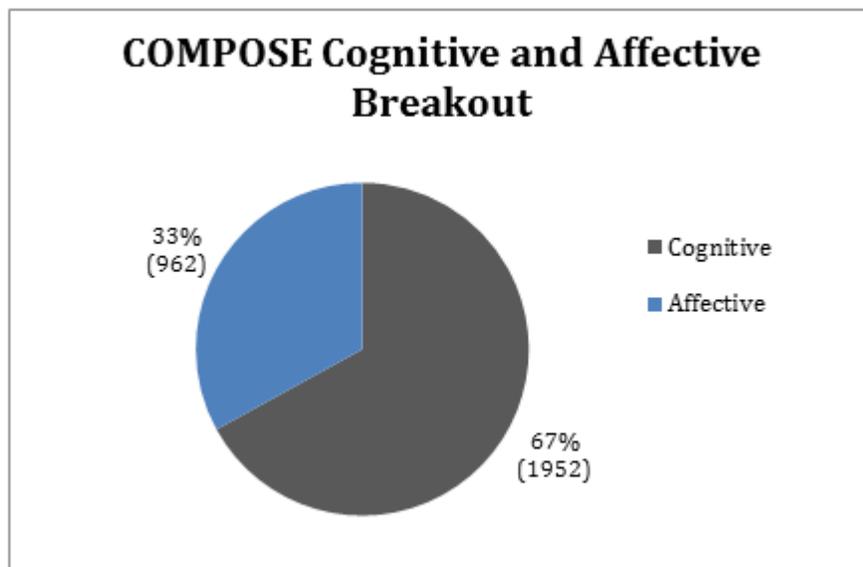


Figure 14. COMPOSE Overall Model's Cognitive and Affective Breakout

Within the cognitive domain about 23% of the KSAs are aligned with Remember, 11% Understand and 42% Application as shown in figures 15-16.

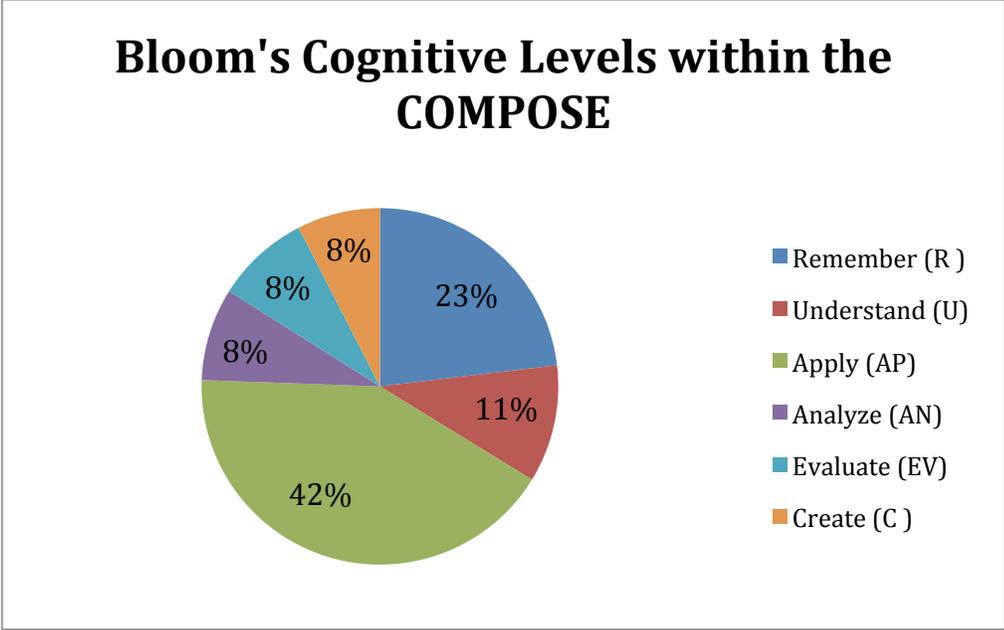


Figure 15. Bloom's Cognitive Levels within the COMPOSE Overall Model

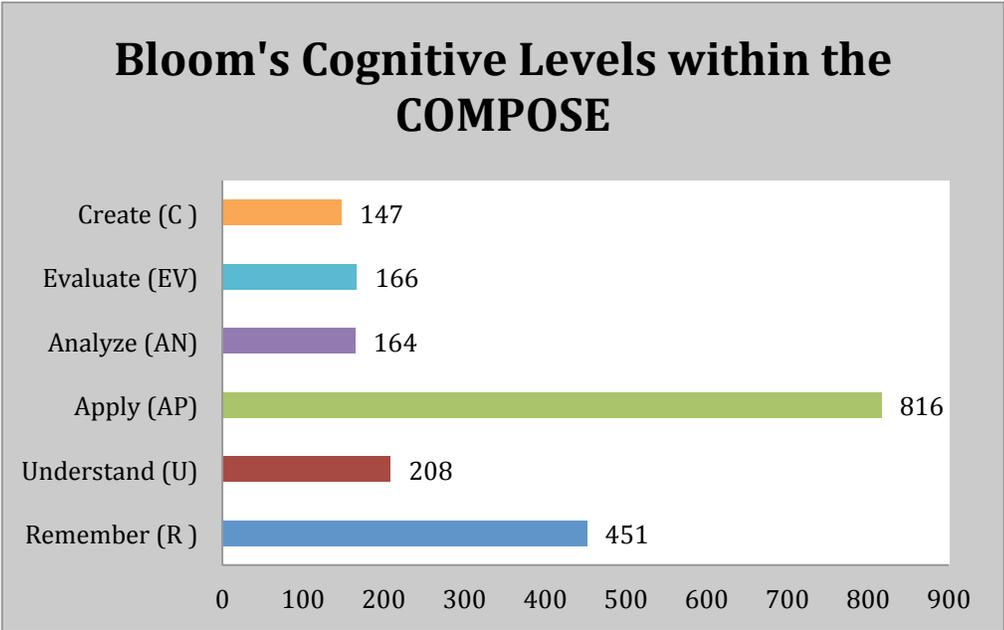


Figure 16. Bar Chart of Bloom's Cognitive Levels within the COMPOSE Overall Model

Within the affective domain about 71% of the KSAs are aligned with Receiving and Responding and 17% with Valuing as shown in figures 13-14.

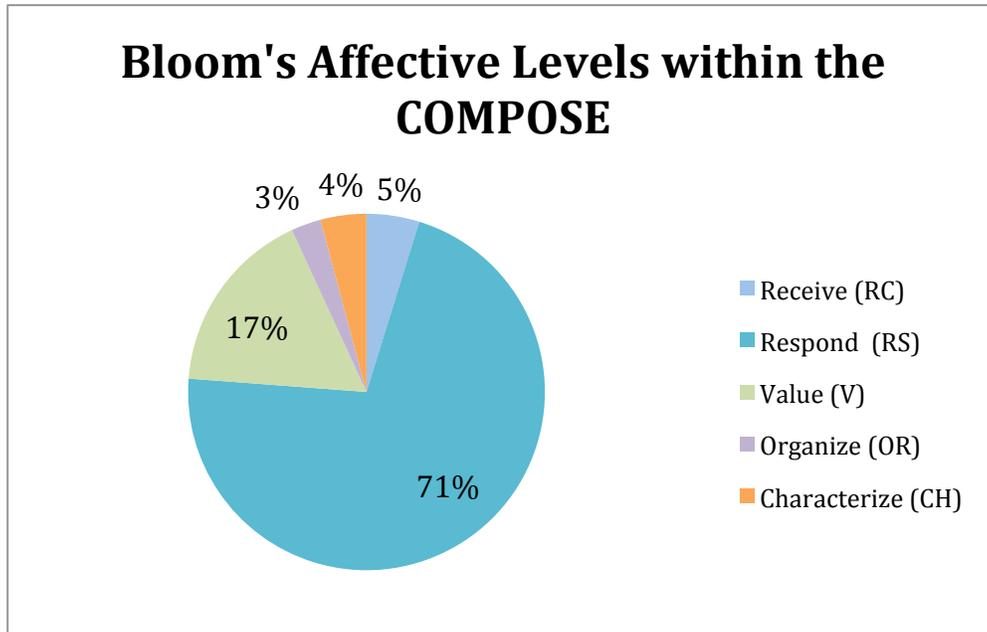


Figure 17. Bloom’s Affective Levels within the COMPOSE Overall Model

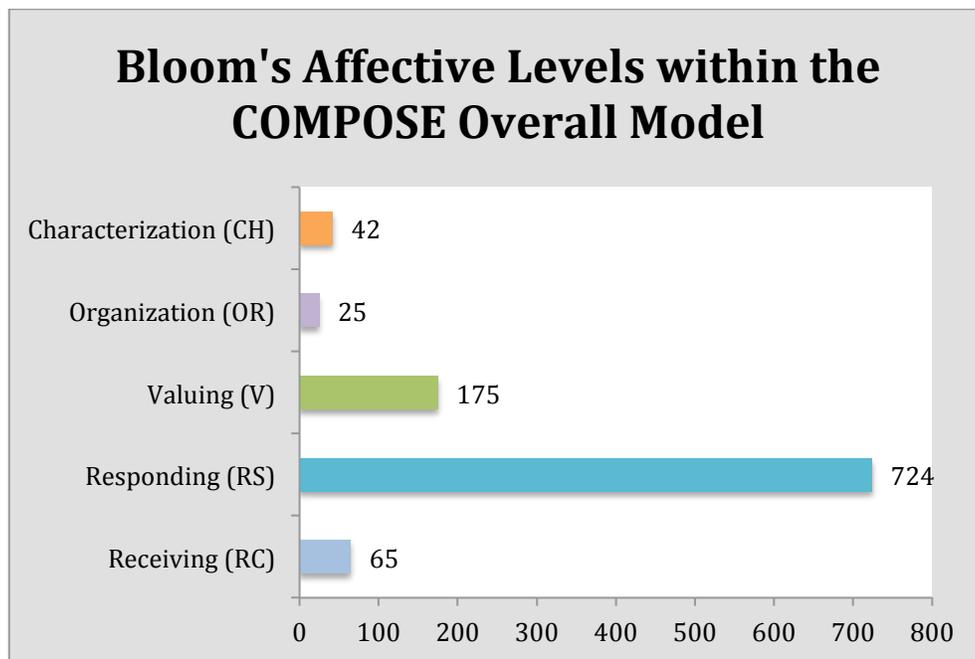


Figure 18. Bar Chart of Bloom’s Affective Levels within the COMPOSE Overall Model

## **B. ANALYSIS**

The COMPOSE model is primarily comprised of KSAs associated with the cognitive domain. Within the cognitive domain about 34% of the KSAs are aligned with Remembering and Understanding and 42% Applying. This implies that a great portion of the COMPOSE model relies heavily on applying the prior knowledge learned. Within the affective domain about 71% of the KSAs are aligned with Receiving and Responding and 17% with Valuing. Although the COMPOSE model consists of mostly KSAs in the cognitive domain, it is also evident that to be a competent SE it is important to have knowledge, critical thinking and the development of intellectual skills from the cognitive domain as well as the emotions, feelings and attitudes that contribute to interpersonal skills from the affective domain.

## **C. SUMMARY**

Analysis of the cognitive and affective levels using Bloom's Taxonomy shows that the majority of the competency model is aligned within the cognitive domain. Application is 42% of the KSAs mapped to the cognitive domain as shown in Figure 15. In the affective domain, responding is 71% of the KSAs as shown in Figure 17.

## V. FINDINGS/RESULTS

This thesis addressed the need for a competency model as a solution to the gap between the current SE competency models and a SE position description for the DOD. This chapter will present the findings and results after analyzing the COMPOSE model.

### A. PRIMARY RESEARCH FINDINGS

Figures 19-21 shows the evolution of KSAs across career levels within the cognitive domain for the COMPOSE model. Initially, in the SE-01 Career Level for the Technical Competency model, the majority of the KSAs are Remember and Understand based within the cognitive domain, which makes sense since these are lower level cognitive domains that can be gathered by training and education. SE-01 is composed of 43% Remembering and 18% Understanding. As the career progresses in SE-02 and SE-03 Career Levels, the focus shifts to Application. At this stage in the career development, the individual is required to apply what was learned to do his/her job. SE-02 is comprised of 48% Application and 9% Understanding, while SE-03 is 53% Application and 7% Analyzing. Figure 22 illustrates the trend of the Bloom's Cognitive levels within the COMPOSE model.

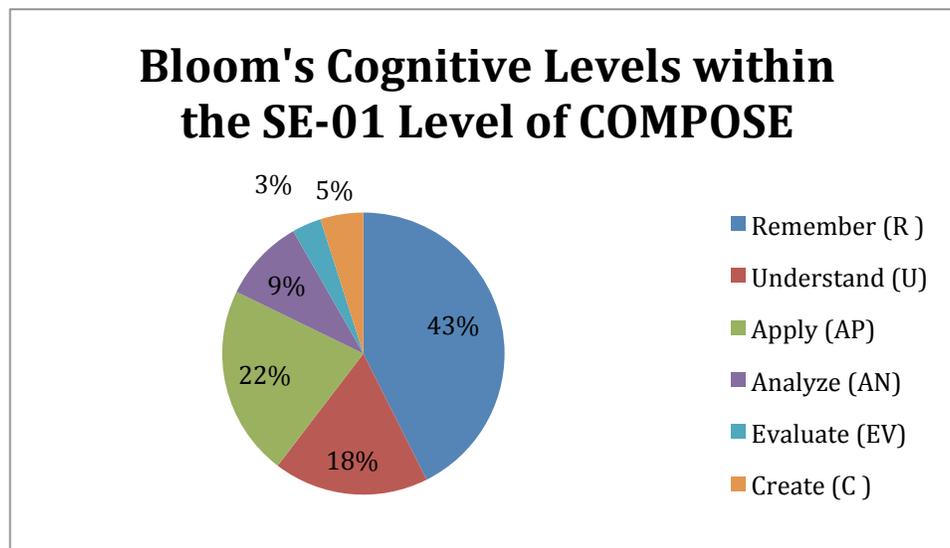


Figure 19. Bloom's Cognitive Levels within the COMPOSE model (SE-01)

### Bloom's Cognitive Levels within the SE-02 Level of COMPOSE

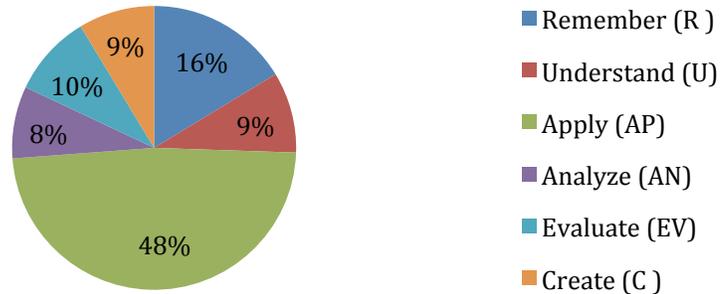


Figure 20. Bloom's Cognitive Levels within the COMPOSE model (SE-02)

### Bloom's Cognitive Levels within the SE-03 Level of COMPOSE

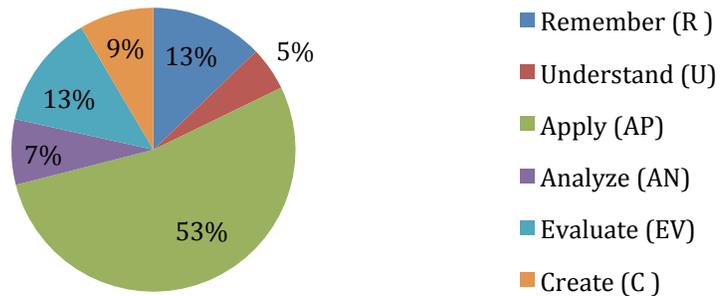


Figure 21. Bloom's Cognitive Levels within the COMPOSE model (SE-03)

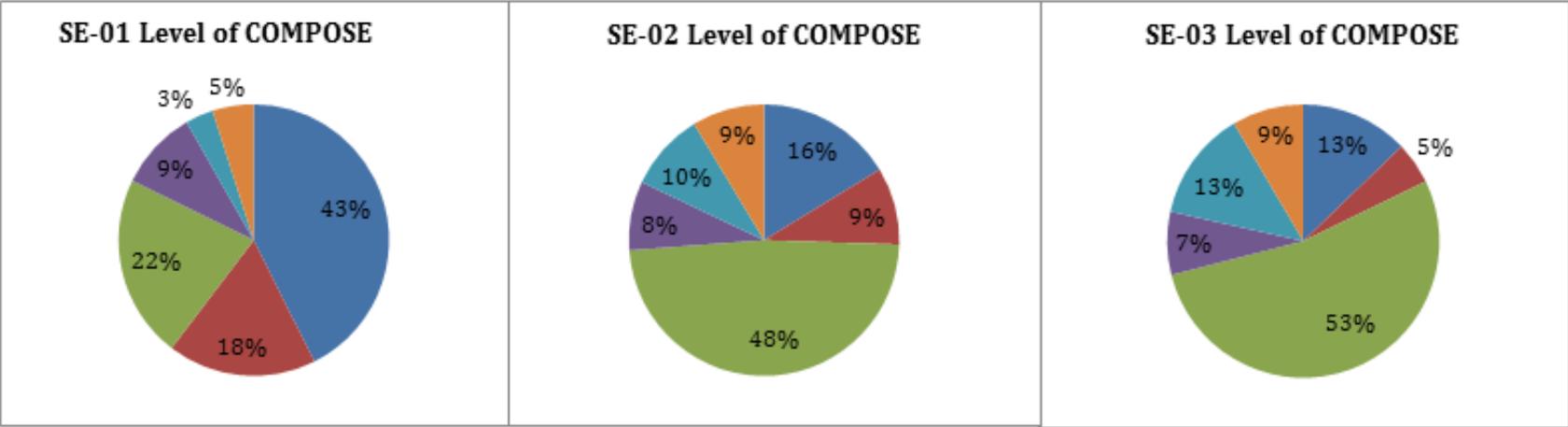


Figure 22. Trend of Bloom's Cognitive Levels within the COMPOSE model, the key is the same as Figures 19-21.

The evolution of KSAs across career levels within the affective domain for the COMPOSE model is represented in figures 23-25. It seems ideal that toward the beginning of the SE-01 and SE-02 career levels, a majority of the KSAs deal with receiving and responding within the affective domain because these are lower levels within the affective domains that are classified as part of individual's personality traits. The SE-01 Career Level is composed of 81% Responding and 9% Receiving. The SE-02 Level is comprised of mostly Responding and Valuing. The SE-03 is representative of Valuing, Characterization and Responding. Figure 26 illustrates the trend of Bloom's Affective levels within the COMPOSE model.

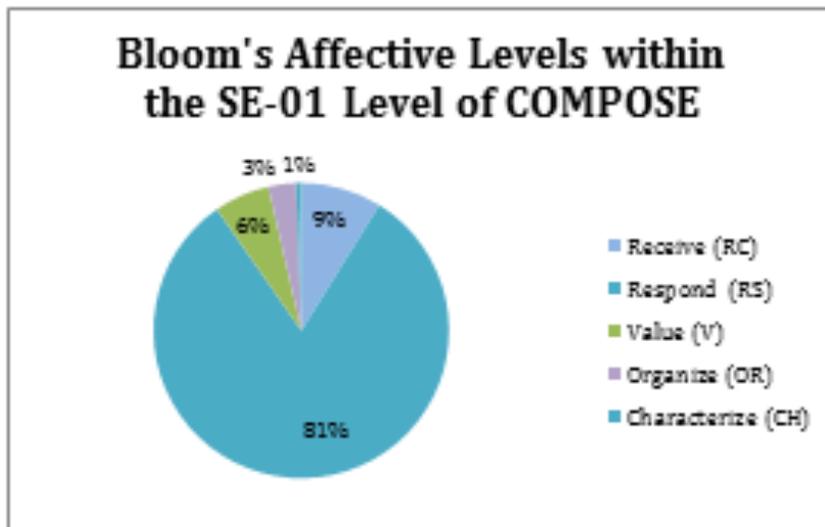


Figure 23. Bloom's Affective Levels within the COMPOSE model (SE-01)

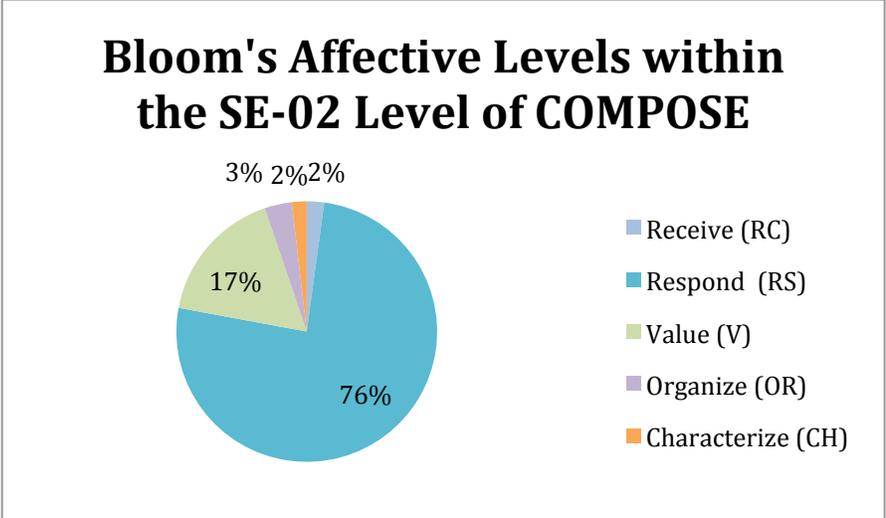


Figure 24. Bloom's Affective Levels within the COMPOSE model (SE-02)

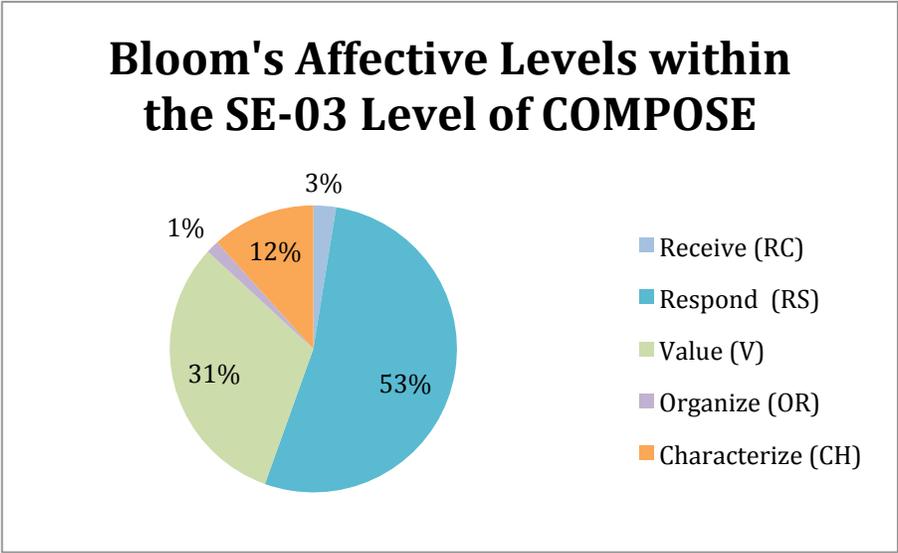


Figure 25. Bloom's Affective Levels within the COMPOSE model (SE-03)

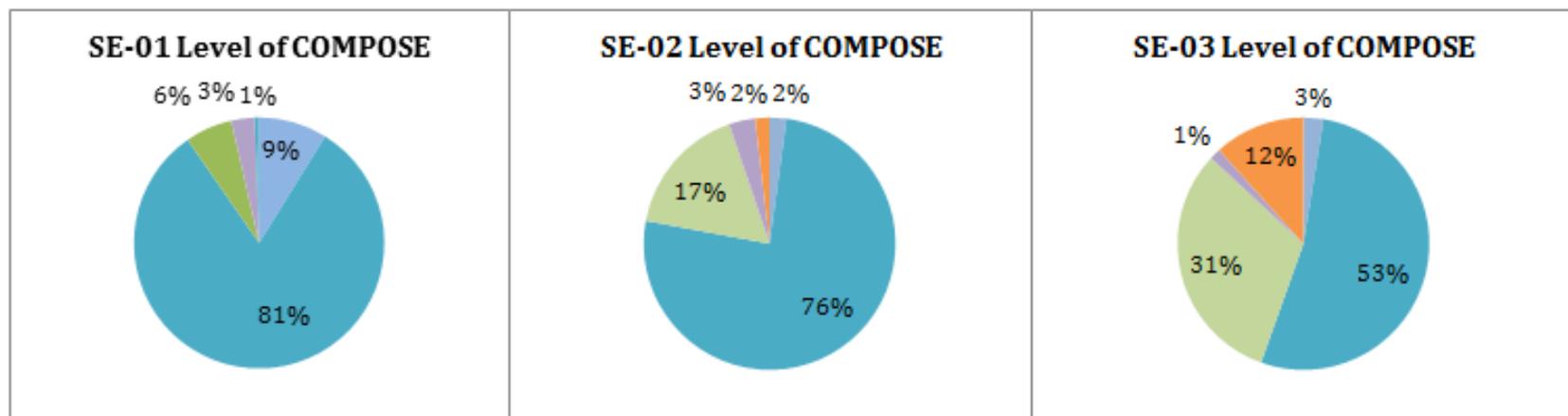


Figure 26. Trend of Bloom's Affective Levels within the COMPOSE model, the key is the same as figures 23-25.

## B. OTHER FINDINGS

As previously stated, the COMPOSE model is continuously evolving. SPAWAR has taken the COMPOSE V0.5 model as a foundation to create their SE Competency model. Figure 27 shows that about 14% of the COMPOSE was used directly. The model is still in the early stages of development and although one is unable to calculate exactly, a large amount of the remaining 86% was also used, but it was tailored to meet the needs of the SPAWAR specifically. This validates that the COMPOSE model can be used as a foundation and tailored to meet an organization's needs while developing a SE Competency model. In the future the COMPOSE model will be shared with other organizations and the capability to track the amount of the COMPOSE model used directly and indirectly in a newly developed SE Competency model will be incorporated.

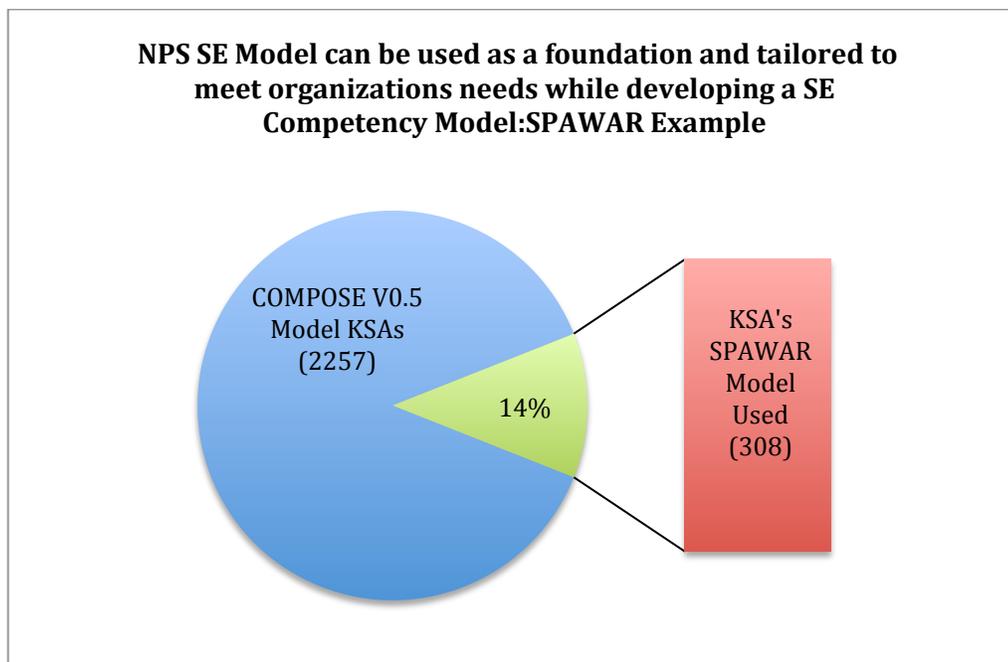


Figure 27. SPAWAR Example

The KSAs taken directly from the COMPOSE V0.5 model and used in the SPAWAR model are shown in Figure 28. The competency model has evolved since then. This analysis is based on the COMPOSE V0.5 model, the model has evolved and the

most recent version of the model COMPOSE V0.78 model has updated competencies. Additionally, the V0.5 Model is aligned to GRCSE Bloom's Taxonomy, while the V0.78 Model is aligned to Krathwohl's Bloom's Update. Figure 29 compares the KSAs mapped to the cognitive SPAWAR's model with the COMPOSE V0.5 model using GRCSE Bloom's Taxonomy. In the COMPOSE V0.5 model competencies 25. System of Systems, 5.0 Requirements Analysis, 16.0 Technical Assessment and 6.0 Architecture Design Competencies represent more than 10% of KSAs from the COMPOSE that SPAWAR used in their SE Competency model. Within the overlap, when comparing the cognitive domains in both models, some similarities and differences are evident as shown in Figure 37. Walter's work also reveals that the majority of the KSAs in SPAWAR's SE Competency model require Application as shown in Figure 29 (Walter 2013). Additionally, Knowledge is very important (38%) in the SPAWAR model, while Comprehension is important (14%) in the COMPOSE model.

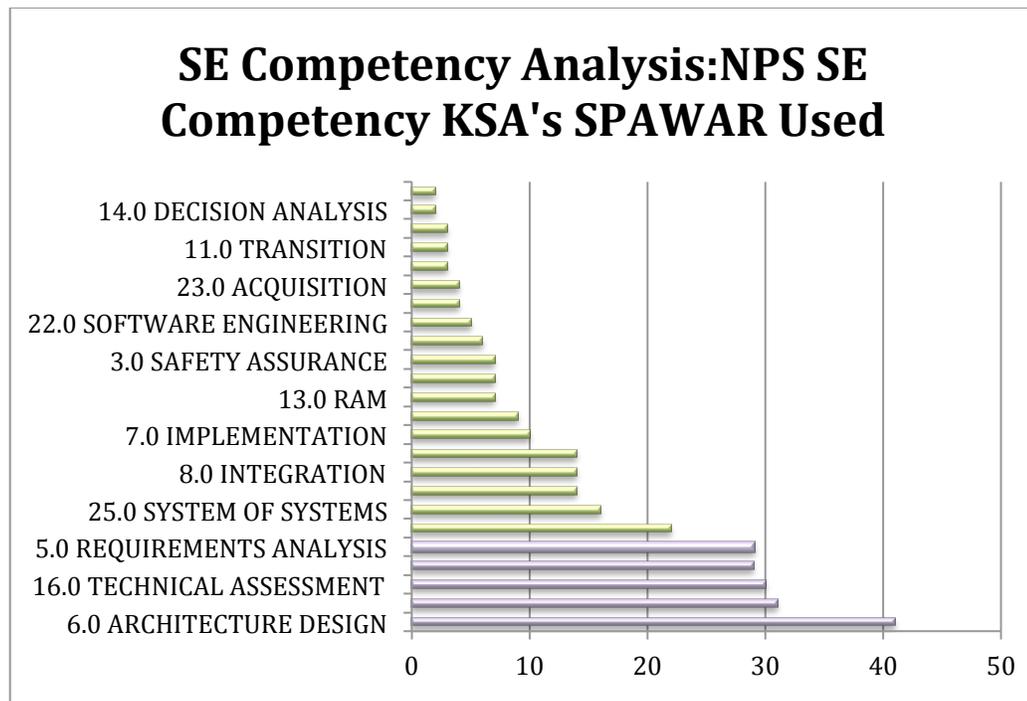


Figure 28. KSAs from the COMPOSE model used by SPAWAR

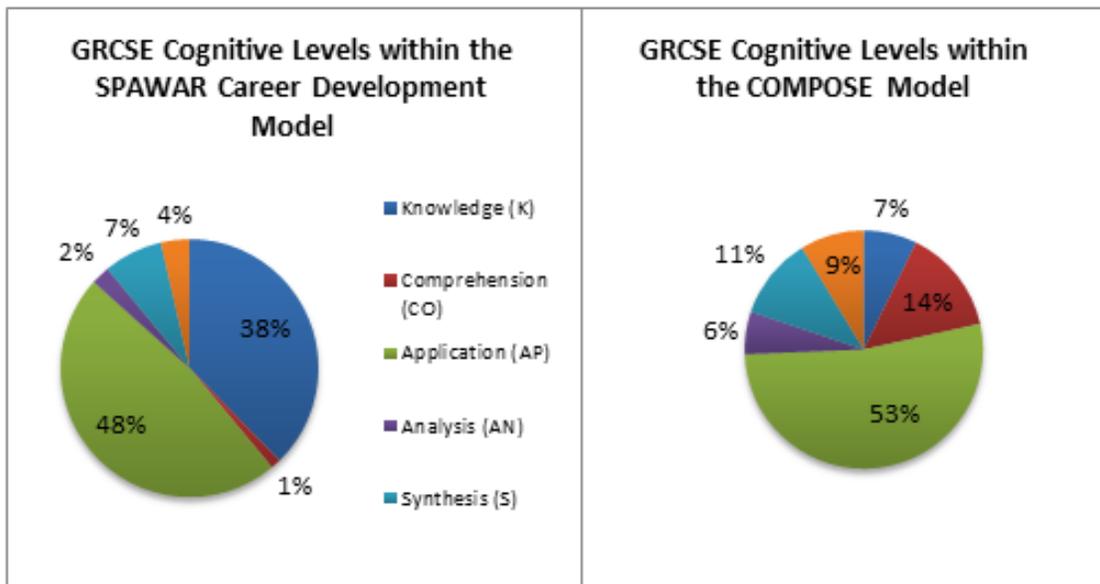


Figure 29. SPAWAR vs. COMPOSE model Cognitive Domain

Alexander’s work emphasizes that in general, DAU covers the knowledge and comprehension levels of Bloom’s taxonomy sufficiently. The majority of KSAs are knowledge and comprehension as shown in Figure 30. Therefore, for KSAs that are associated with basic DOD-generic (as opposed to SSC Atlantic-specific) knowledge and comprehension, it makes sense for DAU training to be the preferred KSAs development method (Alexander 2013).

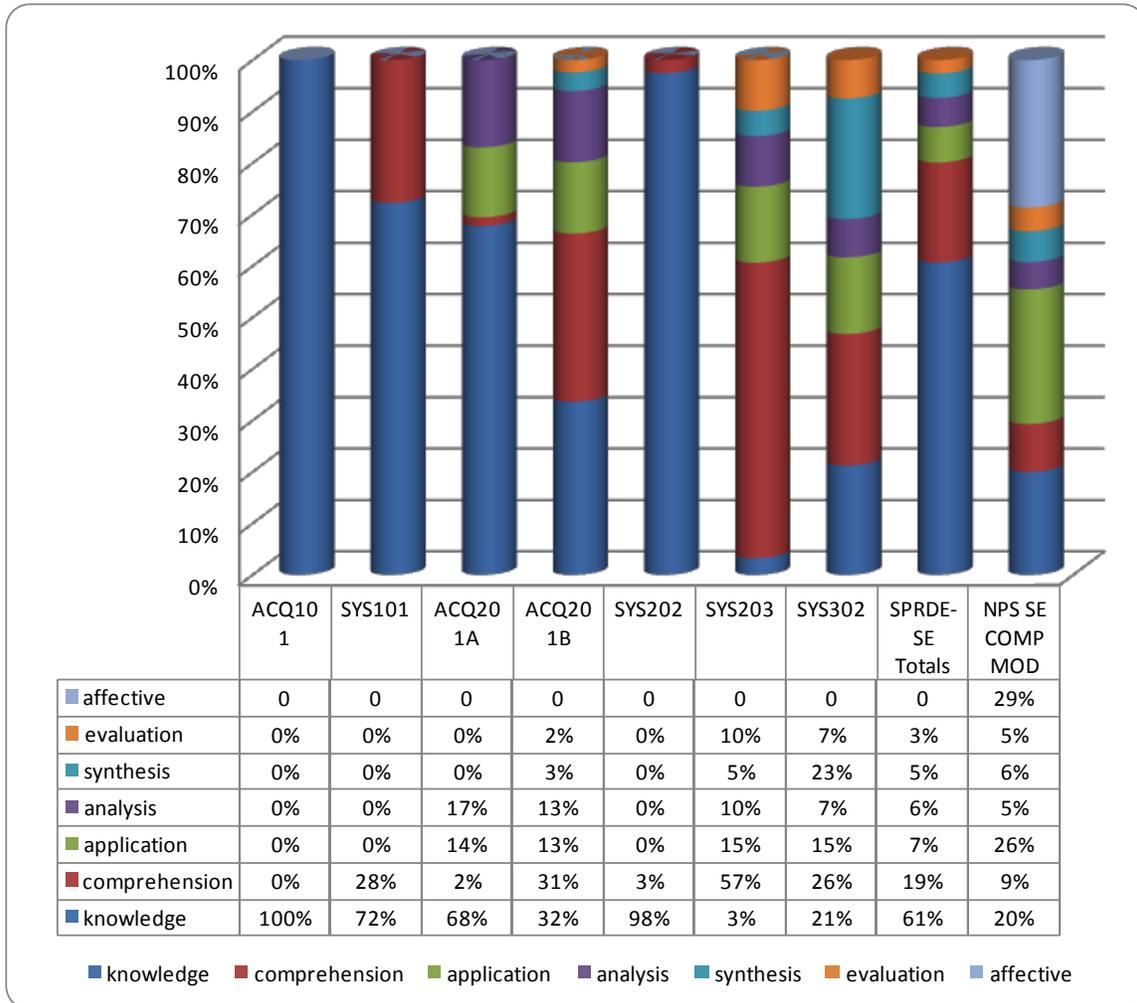


Figure 30. Cognitive Levels of DAU SPRDE-SE Level II Curriculum and NPS SE Competency Model (from Alexander 2013)

### **C. RESEARCH QUESTIONS FINDINGS**

While studying the attributes required to create a useful naval systems engineering competency model, a set of additional secondary research questions surfaced. The first secondary research question is to identify what competencies are required for naval systems engineering. The COMPOSE model identifies forty-one competencies required for naval systems engineering. Secondly, it pinpoints what KSAs are required for development of naval systems engineering competencies at various levels. The model has over 2,914 KSAs mapped across the forty-one competencies. Finally, how does the use of Bloom's Taxonomy for KSAs definition relate to competency development along a career path? After analyzing the COMPOSE model, in the SE-01 Career Level the KSAs were associated with the lower level cognitive and affective domains. Knowledge, comprehension, receiving and responding are all competencies that can be gathered by training and education. As the career progresses in SE-02 and SE-03 Career Levels, the focus shifts to application. At this stage in the career development, the individual is required to apply what was learned to do his/her job.

In the affective domain it seems ideal that toward the beginning of the SE-01 and SE-02 career levels, a majority of the KSAs deal with receiving and responding within the affective domain. These are lower level affective domains that are classified as a part of the individual's personality traits. The SE-01 Career Level is composed of 81% Responding and 9% Receiving. The SE-02 level is comprised of mostly Responding and Valuing. The SE-03 level is representative of Valuing, Characterization and Responding.

The primary research question is to explore what a systems engineering competency model would consist of at the general naval systems commands to use for career planning and tracking competency development. The COMPOSE model MS Excel spreadsheet is an interactive model composed of KSAs aligned to specific competencies across Bloom's cognitive and affective domains. To address the application of these competencies across proficiency levels, each KSAs was mapped to one of three specific career levels designated as SE-1 Entry Level, SE-2 Journey Level or SE-3 Expert Level. The source to obtain competence for each KSAs was also categorized as to whether they would be developed by "Education and Training;" "On the Job Experience;" or "Professional Development."

Initially, in the SE-01 Career Level for the Technical Competency model, the majority of the KSAs are Knowledge and Comprehension based within the cognitive domain, which makes sense since these are lower level cognitive domains that can be gathered by training and education. SE-01 is composed of 43% Remembering and 18% Understanding. As the career progresses in SE-02 and SE-03 Career Levels, the focus shifts to Application. At this stage in the career development, the individual is required to apply what was learned to do his/her job.

The evolution of KSAs across career levels within the affective domain for the COMPOSE professional model. Interestingly, when taking a look at the affective domain with the Professional Skills Competency model, it is clear that the three career levels all look very similar. Majority of the KSAs are categorized as Responding and Valuing. Throughout each of the Career Levels Responding and Valuing are the main focuses.

Other findings include that the KSAs taken directly from the COMPOSE V0.5 and used in the SPAWAR model. SPAWAR used more than 10% of KSAs from the COMPOSE 0.5 model in their SE Competency Model. There is a 14% overlap between the COMPOSE and SPAWAR competency models. Within that overlap, when comparing the cognitive domains in the model the majority of the KSAs require Application. Additionally, Knowledge is very important (38%) in the SPAWAR model, while Comprehension is important in the COMPOSE model.

#### **D. CHAPTER SUMMARY**

This chapter discussed trends and findings when analyzing the COMPOSE model to include how the COMPOSE model was used as a foundation for SPAWAR's SE Competency model. Similarities between SPAWAR's model and the COMPOSE model were provided using pie charts and bar graphs.

## **VI. SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND FURTHER RESEARCH**

This chapter presents a brief summary of the research conducted in order to address the need for a SE position description and career development plan. The development of the COMPOSE model is summarized, conclusions from the analysis of the data are presented, recommendations about the next steps to take are provided and further areas of research are discussed.

### **A. SUMMARY**

The COMPOSE model developed by the NPS systems engineering (SE) team includes SE career development to include: knowledge, skills, abilities and behaviors, and related education, training, and experience needed. It also provides a way to define career paths for systems engineers (jobs, assignments, and timing) based on Bloom's Taxonomy Cognitive and Affective domains. The COMPOSE model and Bloom's Taxonomy both provide hierarchical outcome categories or levels that range from simple to complex thought processes. Once the Bloom's level for each KSAs was identified, the KSAs in each competency were divided into the three career levels by assigning the KSAs with lower Bloom's level ratings to the SE-1 Entry Level, the KSAs with intermediate Bloom's level ratings to SE-2 Journey Level and the KSAs with higher Bloom's level ratings to the SE-2 Expert Level.

Because of the way that the COMPOSE model is formatted, the COMPOSE model can be used by organizations to identify KSAs pertinent to the development of systems engineers. The model will also allow organizations to formulate competency development plans for the professional development of systems engineers. Finally, the model will contribute to the guidance for development of graduate and undergraduate curricula in systems engineering.

The COMPOSE model encompasses eight different systems engineering competency models, which includes INCOSE UK, Boeing, NASA, DAU SPRDE and NUWC Newport. They combine and harmonize with Krathwohl's version of Bloom's Taxonomy based on affinity in the KSAs. The KSAs are re-aligned to fit the model by

eliminating duplication, items that do not fit and are re-categorized based on how each KSAs is written. The COMPOSE model has a total of forty-one competencies and 2,914 KSAs.

Initially, in the SE-01 Career Level for the Technical Competency model, the majority of the KSAs are Remember and Understand based within the cognitive domain, which makes sense since these are lower level cognitive domains that can be gathered by training and education. SE-01 is composed of 43% Remembering and 18% Understanding. Analysis results indicate that when it comes to technical competency within Systems Engineering, at entry-level positions lower level KSAs from the cognitive domain are required. As the career level increases, so does the complexity of the KSAs within the cognitive domain. The SE-02 and SE-03 career level's focus shifts to Application. At this stage in the career development, the individual is required to apply what was learned to do his/her job. SE-02 is comprised of 48% Application and 9% Understanding, while SE-03 is 53% Application and 7% Analyzing. Although the model is still being refined, the initial results indicate that it can be used as a foundation for an organization to tailor to develop a systems engineering competency development model.

## **B. CONCLUSIONS AND RECOMMENDATIONS**

The Competency model for the Profession of Systems Engineering (COMPOSE) consists of 41 competencies and over 2,914 KSAs defined using Bloom's Taxonomy Cognitive and Affective domains that span across three experience levels. Proficiency levels within each experience level are also identified. The model is formatted in a MS Excel spreadsheet which could be provided to any organization to use and tailor the model to meet their organizational needs easily. This spreadsheet was designed to be highly interactive, especially when using the extensive filtering capabilities of the spreadsheet. Organizations should be able to take the model and use it as a foundation to create a competency model that meets their organizational needs. Based on the input, tables are automatically generated in the excel spreadsheet. These tables could easily be incorporated into a more formal competency report document format.

SPAWAR SC Atlantic has taken the COMPOSE V0.5 model as a foundation to create their SE Competency model. About 14% of the COMPOSE V0.5 model was used

directly. The model is still in the early stages of development and although we are unable to calculate exactly, a large amount of the remaining 86% was also used, but it was tailored to meet the needs of the SPAWAR specifically. This validates that the COMPOSE model can be used as a foundation and tailored to meet an organizations needs while developing a SE Competency model. In the future it is recommended to share the COMPOSE model with other organizations to identify which attributes are used directly and indirectly in order to develop a new SE Competency model.

### C. FURTHER RESEARCH

While studying the attributes required to create a useful naval systems engineering competency model opportunities for further research efforts were identified.

- **Future Research Opportunity 1:** How do these competencies and KSAs trend along a career path for various systems engineers?
- **Future Research Opportunity 2:** Evaluate the model using Office of Personnel (OPM) guidelines.
- **Future Research Opportunity 3:** How could a systems engineering competency model be used to inform undergraduate and graduate education programs for systems engineering?
- **Future Research Opportunity 4:** How could an assessment procedure within the competency model be beneficial in addition including a framework for validating assessments?
- **Future Research Opportunity 5:** It would be interesting to analyze exactly how the COMPOSE was used in a given organization after adopted. For example, what percentage of the model was used to create job descriptions, initiate training requirements or create performance evaluation measures?
- **Future Research Opportunity 6:** Re-categorize the model to compliment the DAU SE Competency model.

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## APPENDIX A. EXAMPLES OF CAREER LEVELS FOR THE V0.78 COMPOSE MODEL

Entry Level: 11.0 Tools and Techniques

Knowledge Skills & Abilities (KSAs)	Education	Training	On the Job Experience
Cognitive & Affective Skill Levels			
<b>Remember, Understand, Receive Phenomena &amp; Respond to Phenomena</b>			
Understand the scope and limitations of models and simulations, including definition, implementation and analysis	x		
Understand the need for system representations	x		
Understand the different types of modeling and simulation	x		
Support the M&S specialist in creating and validating models			x
Support systems studies and analyses			x
Participate in networked and federated M&S developments (e.g., training exercise support or simulation war games), with assistance from the specialist		x	
Know which models, simulations, or decision support tools can be used to support your analysis, evaluation, instruction, training or experiment	x		
Know various models & simulations and when it is beneficial to integrate them	x		
Know the right model or simulation to meet your specific needs	x		
Know decision support tools, models, or simulations that are applicable to your job	x		
Collaborate with the specialist to run M&S scenarios, based on current and future operational capabilities			x
Assist the specialist with collecting data and formulating assumptions to create and validate simple simulation models (e.g., operational capabilities, networking, computing resources, and processes)			x
<b>Apply, Analyze, &amp; Value</b>			
Demonstrate candidate modeling and/or simulation approach (e.g., constructive, virtual, and live synthetic environments) while working with the specialist			x
Build prototypes or design experiments to test system concepts and their feasibility	x		
<b>Evaluate, Create, Organize &amp; Characterize by a Value</b>			
Survey existing data and previous modeling efforts to incorporate previous M&S capabilities into the current effort			x
Identify potential integration and interoperability links within and between modeling and simulation tools and synthetic environments		x	

## Journey Level: 11.0 Tools and Techniques

<b>Knowledge Skills &amp; Abilities (KSAs)</b>			
<b>Cognitive &amp; Affective Skill Levels</b>	<b>Education</b>	<b>Training</b>	<b>On the Job Experience</b>
<b>Remember, Understand, Receive Phenomena &amp; Respond to Phenomena</b>			
Understand the risks of using models and simulations which are outside the validated limits		x	
Models systems of varying complexities in their environments	x		
Know how to run and interpret the output of modeling and simulation tools, to provide insight or training to real world situations	x		
Know how to initialize the modeling and simulation tools		x	
Collaborate with the specialist to interpret the results of various M&S scenarios, based on current and future operational capabilities			x
Select appropriate tools and techniques for functional analysis	x		
Define a process that includes requirements for appropriate tools and techniques for architectural design	x		
Use scenarios to determine robustness	x		
Contribute to definition of design and product constraints for a subsystem or simple project			x
<b>Apply, Analyze, &amp; Value</b>			
Apply models, simulations and/or decision support tools	x		
Evaluate models, simulations and/or decision support tools	x		
Evolve models and/or simulations	x		
Employ models and/or simulations	x		
Integrate models and/or simulations	x		
Manage models and/or simulations	x		
Apply models and/or simulations	x		
Develop models and/or simulations	x		
Determine requirements for the application of models and/or simulations	x		
Define an appropriate representation of a system or system element	x		
Collaborate with the specialist to develop assumptions and scenarios, and create and validate complex simulation models (e.g., operational capabilities, networking, computing resources, and processes)			x
Collaborate with the M&S specialist to identify Approach, create and validate models, interpret results, and participate in cooperative modeling arrangements			x
Apply real-world data in models or simulations for computer generated forces, mathematical modeling, physical modeling, scientific research, and statistical analysis			x
Analyze models, simulations and/or decision support tools	x		
Perform Value Engineering, an organized, systematic technique to analyze the functions of systems, equipment, facilities, services, and supplies to ensure they achieve their essential functions at the lowest life-cycle cost consistent with required performance, reliability, quality, and safety		x	
Perform sustainability analyses to reduce system total ownership cost by uncovering previously hidden or ignored life-cycle costs, leading to more informed decisions earlier in the acquisition life cycle		x	
Evolve the authoritative model of the system under development		x	
Employ the authoritative model of the system under development		x	
Integrate the authoritative model of the system under development		x	
Manage the authorities model of the system under development		x	
Develop the authorities model of the system under development		x	
Apply the authoritative model of the system under development		x	
Interpret modeling or simulation results to more fully explore concepts, refine system characteristics/designs, assess overall system performance, and better inform acquisition program decisions		x	
Provide technical basis for program budgets that reflect program phase requirements and best practices using knowledge of Earned Value Management, cost drivers, risk factors, and historical documentation (e.g. hardware, operational software, lab/support software)		x	
Provide technical basis for comprehensive cost Estimate that reflect program phase requirements and best practices using knowledge of Earned Value Management, cost drivers, risk factors, and historical documentation (e.g. hardware, operational software, lab/support software)		x	

<b>Knowledge Skills &amp; Abilities (KSAs)</b>			
<b>Cognitive &amp; Affective Skill Levels</b>	<b>Education</b>	<b>Training</b>	<b>On the Job Experience</b>
<b>Evaluate, Create, Organize &amp; Characterize by a Value</b>			
Suggest collaboration with other organizations to establish integration and interoperability within and between modeling and simulation tools and synthetic environments			x
Plan models or simulations to drive exercises		x	
Identify Approach, tools, and techniques to describe, analyze, and synthesize complicated and complex systems	x		
Execute models or simulations to drive exercises		x	
Compare the strengths and limitations of modeling and simulation Approach, identify Approach that fit the scope, and define the visualization approach while working with the specialist			x
Ensure credibility of models or simulations by adhering to and applying sound verification, validation and accreditation (VV&A) practices			x
Create a comprehensive, integrated model that Describe systems of varying complexities in their environments, including systems dynamics (e.g. human, organizational and technical dynamics)		x	
Develop innovative solutions that include S&T developmental prototyping, experimentation and visualization techniques	x		

## Expert Level: 11.0 Tools and Techniques

<b>Knowledge Skills &amp; Abilities (KSAs)</b>			
Cognitive & Affective Skill Levels	Education	Training	On the Job Experience
<b>Remember, Understand, Receive Phenomena &amp; Respond to Phenomena</b>			
Present to the sponsor/customer and key stakeholders a comprehensive, integrated model that Describe systems of varying complexities in their environments, including systems dynamics (e.g. human, organizational and technical dynamics)			x
Describe the VV&A process		x	
Describe the M&S planning process as a support tool for systems engineering		x	
Describe the M&S hierarchy		x	
Define the strategy and approach to be adopted for the modeling and simulation of a system or system element	x		
<b>Apply, Analyze, &amp; Value</b>			
Recommend the scope of modeling, simulation and analysis activities within and across projects/programs, with input from the modeling and simulation specialist			x
Recommend modeling and simulation Approach within and across projects, programs, and enterprises, including the visualization approach			x
Recommend M&S scope, Approach, and changes to operational capabilities, and Facilitate cooperative modeling arrangements			x
Recommend changes to current and future operational capabilities based on modeling and simulation results			x
Provide expert technical advice on the verification, validation and accreditation of models or simulations		x	
Provide expert technical advice on model or simulation architectures		x	
Manage/supervise the development and application of models and/or simulations for a Program			x
Lead networked and federated M&S developments (e.g. major training exercises or simulation war games), with assistance from the specialist			x
Guide the formulation of assumptions and scenarios developed by the specialist to create complex simulation models (e.g., operational capabilities, networking, computing resources, and processes)			x
Explain the difference between fidelity and resolution		x	
Explain the difference between a model and a simulation		x	
Explain the application of modeling and simulation to systems engineering.		x	
Update modeling and simulation standards, policy, and guidance for an organization		x	
Review modeling and simulation standards, policy, and guidance			x
Develop modeling and simulation standards, policy, and guidance		x	
Demonstrate a full understanding of complex simulations for a system or system element			x
Apply doctrinal and operational knowledge during simulation exercise execution			x
Advise on the suitability and limitations of models and simulations			x

## APPENDIX B. SE COMPETENCY OBJECTIVES



### SE Competency: Cognitive & Affective Components



#### Objectives

- Develop competency model and identify and evaluate the cognitive and affective domains associated with SE KSA.
- Define KSAs using **Bloom's Taxonomy**: Cognitive and Affective Domains.
- Harmonize SE Competency Career Development Model with GRCSE.
- Develop an approach and methodology to obtain baseline information needed for the Naval SE Competency Model life cycle development (knowledge, skills, abilities and behaviors, and related education, training, and experience needed).
- Define career paths for systems engineers (jobs, assignments, and timing).
- Document results.

**Faculty** Cliff Whitcomb  
**Sponsor** DASN  
**Partners** Naval SYSCOMS  
**Student** Corina White  
**Grad** June 2014

#### Approach

- Develop Excel spreadsheet based SE Competency Career Development Model
- Utilize Bloom's Taxonomy to define KSA in cognitive and affective domains
- Analyze the cognitive/affective skills needed to develop as a proficient SE
- Document results in a thesis

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# APPENDIX C. KRATHWOHL COGNITIVE AND AFFECTIVE DOMAINS

## Cognitive Domain (adapted from Bloom's)



LEVEL	EXAMPLE COMPETENCIES
<b>Remember (C)</b>	<ul style="list-style-type: none"> <li>The student is able to recite the definitions of "system" and "emergence" and state the connection between them.</li> <li>The student is able to describe the notion of product system architecture and state the impact architecture may have on system development success.</li> </ul>
<b>Understand (U)</b>	<ul style="list-style-type: none"> <li>The student is able to explain, in a very general way, the conditions under which a system development team might choose to use a waterfall (or iterative, incremental, or spiral) life cycle model.</li> <li>The student is able to explain the range of cases for which a particular systems modeling approach is applicable.</li> </ul>
<b>Apply (AP)</b>	<ul style="list-style-type: none"> <li>Given the operational concept and requirements of a simple system along with a specified budget and required completion time, the student is able to choose (and to provide a rudimentary justification for the choice) a particular life cycle model to address the project; e.g., waterfall, iterative, incremental, or spiral.</li> <li>The student is able to construct a simple model of a defined system that would demonstrate understanding of the relationship of the primary factors included in the model.</li> </ul>
<b>Analyze(AN)</b>	<ul style="list-style-type: none"> <li>Given a simple requirements document and a domain model for an application, the student is able to critique the domain model.</li> <li>Given the operational concept of a system along with a requirements document, a budget, a schedule, a choice of a development process, and a justification of the use of that process for the project, the student is able to find and explain errors in the justification and/or in the choice of the process.</li> <li>The student can analyze the effectiveness of a simple model of a system to describe the behavior of that system and identify errors or weaknesses in the model arising from the assumptions about the system embedded in the model.</li> </ul>
<b>Evaluate (EV)</b>	<ul style="list-style-type: none"> <li>Given a detailed requirements document and a well-constructed domain model for a system, the student is able to design at least one basic architecture for the system.</li> <li>Given an operational concept, requirements, architecture, and detailed design documents for a system, the student is able to construct a complete implementation plan and provide a cogent argument that if the implementation of the architecture or detailed design is performed according to the plan, then the result will be a system that satisfies the requirements, fulfills the operational concept, and will be completed within the budget and schedule.</li> <li>The student can develop and use a model of a simple system where the system is described by architecture to determine the capability of the system represented by the model and to explore desirable parameters of model elements.</li> </ul>
<b>Create (C)</b>	<ul style="list-style-type: none"> <li>Given an operational concept, requirements, architecture, a detailed design, and an implementation plan, including budget and schedule, for a system, as well as a feasibility argument for the implementation plan, the student is able to assess the plan and to either explain why the feasibility argument is valid or why and where it is flawed with regard to any of the claims regarding implementation of the requirements, fulfillment of the operational concept, or the ability to be completed within budget and schedule.</li> <li>Given a simple system, the student is able to plan a test and evaluation method to perform a verification and validation process of that system against the requirements of the system and the need description associated with the system.</li> <li>Given a simple system and a test and evaluation plan of the system, the student is able to determine that the results that would be produced through use of the test and evaluation plan will yield a useful verification and validation of the system.</li> </ul>

1/17/14

25

# Affective Domain (adapted from Bloom's)



LEVEL	EXAMPLE COMPETENCIES
<b>Receive (RC)</b>	<ul style="list-style-type: none"> <li>• The student accepts that customer or user perception of the quality of a system is the fundamental determinant of system quality.</li> <li>• The student accepts that customers do not always fully describe what they want or need, and that there is a difference between what customers say they want and what they actually need.</li> <li>• The student is able to describe the value of the SE approach to design.</li> </ul>
<b>Respond (RS)</b>	<ul style="list-style-type: none"> <li>• The student learns how to ask questions to elicit the unstated desires of a stakeholder who is seeking a system development.</li> <li>• The student is willing to try the SE approach on a small project.</li> </ul>
<b>Value (V)</b>	<ul style="list-style-type: none"> <li>• The student believes it is important to provide system solutions that satisfy the range of stakeholder concerns in a manner that the stakeholders judge to be good.</li> <li>• The student believes it is important to elicit a nuanced description of what stakeholders desire of a system in order to provide rich knowledge that can be used in the system solution development.</li> <li>• The student believes in the value of the application of SE principles in a project, even in the face of advocates for other methods.</li> <li>• The student recognizes the value of advancing in proficiency in SE competencies.</li> </ul>
<b>Organize (OR)</b>	<ul style="list-style-type: none"> <li>• The student is able to organize a coherent framework of beliefs and understandings to support use of a SE method in a project.</li> <li>• The student has a coherent framework for how to discuss system development with stakeholders and to incorporate the views of a variety of stakeholders in a balanced manner.</li> </ul>
<b>Characterize (CH)</b>	<ul style="list-style-type: none"> <li>• The student will routinely approach system development projects with a SE framework.</li> <li>• The student will routinely evaluate the appropriate tailoring of SE processes to appropriately address the specific characteristics of each project.</li> <li>• The student will appropriately weigh the views of all stakeholders and seek to overcome conflicts between stakeholders using methods that are technically and socially appropriate.</li> </ul>

1/17/14

26

## APPENDIX D. KENDALL'S MEMO



ACQUISITION,  
TECHNOLOGY  
AND LOGISTICS

### THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON  
WASHINGTON, DC 20301-3010

SEP 16 2013

MEMORANDUM FOR: SEE DISTRIBUTION

SUBJECT: Sunsetting of the Systems Planning, Research, Development, and Engineering – Program Systems Engineer Acquisition Workforce Career Path and the Renaming of the Systems Planning, Research, Development, and Engineering Acquisition Workforce Career Field

The Deputy Assistant Secretary of Defense for Systems Engineering (DASD(SE)), Mr. Stephen Welby, as the Functional Leader for the Systems Planning, Research, Development, and Engineering (SPRDE) career field, has recommended the sunsetting of the Program Systems Engineer (PSE) acquisition workforce career path. Based on this recommendation, I authorize the sunsetting of the SPRDE-PSE career path, effective October 1, 2013.

Accordingly, the engineers in the “SPRDE-PSE” acquisition workforce career path, as well as all personnel coded within the “SPRDE-Systems Engineering” acquisition workforce career path, will be transitioned to a consolidated and renamed acquisition workforce career field with the general title of “Engineering.” Renaming this career field will emphasize the contribution of these professionals to Department of Defense (DoD) acquisition. This change is effective immediately.

Those acquisition workforce members currently coded under the Defense Civilian Personnel Data System “W” code at Level III in the PSE career path may keep this identifier. The “W” code is not to be used for any new coding after PSE is sunsetted. All others will be recoded to the “S” code. Component Directors for Acquisition Career Management will recode the PSE acquisition workforce/positions as quickly as possible. The Position Category Description for PSE will be eliminated in its entirety.

Members of the SPRDE-PSE acquisition workforce have served DoD and their respective organizations with distinction, and this change in no way reflects on the value they have provided to their organizations. This change has been implemented to simplify processes, reduce cost, and leverage the SPRDE-PSE workforce expertise across the larger Engineering acquisition workforce.

Please direct questions to Mr. Nicholas Torelli, Director, ODASD(SE)/Mission Assurance, at 703-695-2300 or [nicholas.m.torelli.civ@mail.mil](mailto:nicholas.m.torelli.civ@mail.mil).

A handwritten signature in black ink, appearing to read "Frank Kendall", written over a light blue horizontal line.

Frank Kendall

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