Developing Competency-Based Engineering Curriculum and Certifications

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SUMMARY & CONCLUSIONS

The paper presents the framework and processes for the development of competency-based curriculum and certifications to enable members of the engineering community to demonstrate the behaviors, knowledge, skills, and abilities necessary to perform their assignments at the highest levels of proficiency through a mix of experience, training, and education.

The paper is based on the development of LOG 211, “Supportability Analysis” by the Defense Acquisition University (DAU) in meeting certification requirements for the Defense Acquisition Workforce as recommended by the Department of Defense (DOD) Reliability Improvement Working Group [1]. LOG 211 focuses on competencies and proficiencies in the areas of design interface, reliability and maintainability analysis and supportability analysis and uses gaming & simulation to enhance student learning as well as the development of a “capstone” exercise that provides the students artifacts for future reference and use.

1 HUMAN CAPITAL STRATEGIC PLANNING

Human Capital Strategic (HCS) Planning defines the competencies and associated proficiencies and provides a ‘path ahead’ for achieving them. In May 2008, the Department of Defense (DoD) initiated the DoD Human Capital Strategy (HCS) [2] to “…describe the vision for the community, enabling pillars, outcomes, benefits, the implementation approach and a timeline of key actions and tasks…. and to provide a roadmap for human capital strategic planning.” The HCS addresses the educational and certification requirements of all of the Defense Acquisition Workforce Improvement Act (DAWIA) career fields, to include Program Management, Systems Engineering, Test and Evaluation and Life Cycle Logistics.

1.1 Competency Development

The “DoD Core Logistics Competencies and Proficiencies Booklet” [3] dated July 2008 supports the Human Capital Strategy. It defines competencies endorsed by the Office of Personnel Management (OPM), to include the competencies described in the following paragraphs.

1.1.1 Logistics Design Influence

Logistics design influence is defined as the technical and management activities conducted to ensure supportability performance capabilities are considered early and throughout the acquisition process to optimize support costs while providing the user with the resources to support and sustain the system.

1.1.2 Reliability and Maintainability Analysis

Reliability and Maintainability Analysis is a process used to determine an item/system’s failure modes and frequencies, wear characteristics, and their impact on the maintenance planning process.

1.1.3 Supportability Analysis

Supportability analysis is a process used to determine an item/system’s support needs and preferred support methods. Uses the reliability and maintainability, operational requirements, existing support systems and integrated logistics support objectives as inputs and it outputs an integrated support plan for the item/system’s life cycle.

1.2 Proficiency Development

Proficiency levels and measures of knowledge are developed for each of the following four competencies levels of proficiency.

1.2.1 Proficiency Level 1

The supervisor defines the actions, work products, and processes necessary for the employee to accomplish assigned tasks. The supervisor provides direction on a daily of step-by-step basis in order for the employee to complete tasks most effectively. Progress is checked against a timetable on a regular basis.

1.2.2 Proficiency Level 2

The employee prioritizes daily tasks with guidance from the supervisor. The supervisor provides direction on a daily of step-by-step basis in order for the employee to complete tasks most effectively. Progress is checked against a timetable on a regular basis.

1.2.3 Proficiency Level 3

The employee takes the initiative, follow the work plan, check progress against objectives, and report any deviation to the supervisor. The employee works effectively and efficiently
without constant checking by the supervisor. The employee seeks guidance as appropriate on key issues.

1.2.4 Proficiency Level 4

The employee requires minimal supervision, addressing most issues and answering most questions about his/her own area of responsibility. The employee requires little supervision but keeps leadership apprised of project status in a timely manner, raising issues of risk to the appropriate level and at the appropriate time.

1.2.5 Proficiency Level 5

The employee is a recognized expert in a particular area and often handles the most challenging situations. The employee takes responsibility for moving the business in a specific direction and is aware of the external development in his/her area of expertise as well as how these can be leveraged or addressed by DoD.

1.3 Proficiency Measures Of Knowledge

The role of the measures of knowledge for each proficiency level in determining curriculum content is discussed in the following paragraphs.

1.3.1 Use of Tools and Best Practices

Use of use modeling and simulation to support logistics design influence decisions; identification of those best practices associated with existing defense system performance capabilities that have influenced supportability designs and development, such as Prognostics and Health Management (PHM), and Condition-Based Maintenance Plus (CBM+).

1.3.2 Knowledge and application of Policy and Standards

Knowledge and application of policy & standards & other documents - explain logistics design influences, including: availability of technical and product data, designing for support/supportability and Reliability, Availability & Maintainability (RAM), Human Systems Integration (HSI), Environmental, Safety, And Occupational Health (ESOH), Integrated Product And Processes Development (IPPD), and Evolutionary Acquisition Strategies.

1.3.3 Information Collection & Analysis

Analyze enterprise-wide performance metrics to recommend and determine appropriate technical, engineering, and product data management strategies.

1.3.4 Problem Identification & Resolution

Develop a Risk Management Strategy; solve technical or procedural deficiencies resultant from system and equipment performance data analysis; ensure corrective actions are implemented.

1.3.5 Collaboration, Partnering & Relationships

Demonstrate awareness of pertinent stakeholder collaborations; demonstrate awareness of industry capabilities and partnerships; recognize DoD and service/agency organizations that provide policy and technical guidance related to supportability analysis; lead government and industry teams in the resolution of complex technical and business issues; manage relationships with stakeholders; lead transformation efforts to support logistics design influence.

1.3.6 Process Application, Assessment and Integration

Align Life Cycle Management principles to the appropriate Acquisition and Sustainment phases; apply the results of Affordability Analysis to design and sustainment criteria; assess the impact of Configuration Management changes; develop a Data Management Strategy.

1.4 Levels Of Cognitive Order

Proficiencies are progressive in their complexity commensurate with experience, knowledge, skills and abilities, and progress in “levels” starting with simple recall and progressing through the development of abstract concepts. Correspondingly, curriculum (learning) becomes more complex. Bloom’s Levels of Cognitive Order [4] were developed to define this progression. Table 1 identifies and defines the learning levels and links the progression of complexity in terms of the information presented in the course content and the learning to be achieved and ultimately verified through assessment (testing).

<table>
<thead>
<tr>
<th>Learning Level</th>
<th>Definition</th>
<th>Associated Action Verb</th>
<th>Test Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>Recalling of specific bits of information; no comprehension required; memorization</td>
<td>Define, match, repeat, underline, name, label</td>
<td>Multiple choice, completion, true/false Short answer</td>
</tr>
<tr>
<td>Comprehension</td>
<td>Understanding the meaning of material without application</td>
<td>Classify, identify, describe, explain, compare, contrast</td>
<td>Multiple choice, completion, matching, labeling, restricted essay</td>
</tr>
<tr>
<td>Application</td>
<td>Using methods, concepts, principles, and theories in new situations</td>
<td>Apply, show, construct, use, calculate, solve, modify, operate demonstrate, choose, distinguish</td>
<td>Multiple choice, completion, matching, drawing, restricted essay</td>
</tr>
<tr>
<td>Analysis</td>
<td>Breaking down information into its constituent elements</td>
<td>Analyze, examine, resolve, relate, classify, breakdown</td>
<td>Multiple choice, essay, practical exercise</td>
</tr>
<tr>
<td>Synthesis</td>
<td>Putting together new constitute elements or parts to form an original result</td>
<td>Derive, create, generate, design, develop, formulate, organize</td>
<td>Essay, practical exercise, case exercise, develop plans</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Judging the value; applying standards</td>
<td>Assess, defend, judge, criticize, justify</td>
<td>Essay, practical exercise, case exercise, evaluate plans</td>
</tr>
</tbody>
</table>

Table 1 – Bloom’s Cognitive Levels
The complexity of LOG 211 is best reflected by Bloom’s Level 3, Application and Level 4, Analysis. As a result, the course curriculum will focus primarily on use of practical exercises to both facilitate learning and assess achievement; however, some concepts, such as reliability, maintainability, availability and cost trade-off may require Levels 5 and 6 for Synthesis and Evaluation, respectively.

1.5 Assessment

Assessment of learning is based on the strategy established for each course, given its construct and its success criteria, which usually includes the successful transfer of information and the learning gained and retained over time. Again, mastery of the competencies and proficiencies at the defined Bloom’s Level is paramount, and directly impacts the design and frequency of testing and assessment and whether they will be conducted at the individual and group level as well as how they will be graded or evaluated.

2 SUPPORTABILITY ANALYSIS

Supportability is the degree to which system design characteristics and planned logistics resources meet operational and sustainment requirements. Supportability analysis is conducted to ensure Supportability is included as a system performance requirement and that the system is concurrently designed, developed and acquired with the optimal support system and infrastructure.

As described in the DoD’s “Supportability Guide” [5] the System Operational Effectiveness (SOE) uses concept of a System Design for Supportability (SDOE) Model, which focuses on Design Interface and the Supply Chain Model (SCM), which focuses on the logistics activities that enable effective sustainment. As such, Supportability and Supportability Analysis bridge the systems engineering and logistics engineering domains and provide a means of assessing life cycle suitability for operations and support.

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2.1 Design for Support

“Design For Support” starts at the earliest Life Cycle Phase when user needs are identified, capabilities defined and priorities established.

During this phase, Supportability Objectives, their associated metrics and the initial trade studies are conducted within the Systems Engineering - Logistics Engineering process and result in the preferred system design and sustainment architectures with accompanying, specific design criteria.

The preliminary maintenance concept is also defined and specifies in broad terms the levels of maintenance to be implemented, economic guidelines for decisions regarding repair versus discard of failed items at the system and its levels of indenture, and the general assignment of preventive and corrective tasks to be accomplished at each level of maintenance.

The Systems Engineering - Logistics Engineering tasks of Reliability & Maintainability (R&M) Modeling, Prediction, Allocation and Analysis, Failure Modes, Effects and Criticality (FMECA), Fault Tree Analysis and Condition-Based Maintenance Plus (CBM+), to include Prognostics and Health Management (PHM) and Reliability Centered Maintenance (RCM), are conducted and interact to assess the impact of the system’s Reliability and Maintainability design characteristics. These characteristics directly influence the performance and suitability of the design, and manifest themselves in design features resulting in the elimination of single points of failure, enhanced Mean Time Between Failure (MTBF) through redundancy and implementation of accessibility, modularity and testability concepts to reduce Mean Time to Repair (MTTR), and develop an effective construct for conducting maintenance based on the evidence of need rather than defined schedules.

These analyses, when combined with the detailed maintenance information provided by the Maintenance Task Analysis, establish the boundaries for finalizing the Maintenance Concept as documented by the Level of Repair Analysis (LORA), which determines, based on economic criteria, the repair versus discard criteria for failed items and the allocation of both preventive and corrective maintenance, with the attendant facilities, spares, tools, test equipment, personnel and training throughout the levels of maintenance.

2.2 Design The Support

“Design The Support” process is based on the output of the “Design For Support” process as described in the previous paragraph, i.e., the spares, common, peculiar, and unique tools and discrete and automatic test equipment, facilities, and maintenance training must be specified and procured. For example, Support Equipment Recommendation Data (SERD) is generated as part of the Product Support Analysis process to specify measurement requirements and determine if existing equipment can be used or whether new equipment must be designed and procured. Ultimately, the need to provide the resources that ‘Support the Design’ and rival the scope of work required to “Design for Support”.

2.3 Support The Design

The “Support The Design” process is implemented through the resources of the Integrated Product Support Package, and is the ultimate outcome of the Supportability Analysis process. As shown in the figure, the twelve Product Support Elements are defined as a result of a robust Product Support Analysis and provide the assets required for effective sustainment of the system.

2.4 Design Review

The design review process as defined in DoDI 5000.02 [6] design process includes the Preliminary Design Review (PDR) and the Critical Design Review (CDR) to ensure
requirements are defined, traceable throughout the design and that governance evaluates the effectiveness of their implementation and the implications on performance, cost, schedule and sustainment. The DoD Systems Engineering Process uses the Defense Acquisition Program Support (DAPS) Methodology to review the design and ensure supportability metrics are defined, implemented in the design as criteria, and that the design reflects their impact on the system in meeting both performance and sustainment objectives.

2.5 Test & Evaluation (T&E)

Chapter 9 of the Defense Acquisition Guidebook [7], addresses the Developmental Test & Evaluation (DT&E) and Operational Test & Evaluation (OT&E) processes as the principal methods of ensuring the achievement of user needs as expressed in key performance parameters (KPPs).

Developmental Test and Evaluation (DT&E) provides the verification and validation of the Systems Engineering process and must provide confidence that the system design solution is on track to satisfy the desired capabilities. Rigorous component and sub-system DT&E enables performance capability and reliability improvements to be designed into the system early. DT&E events should advance to robust, system-level and system-of-systems level T&E, to ensure that the system has matured to a point where it can enter production, and ultimately meet operational employment requirements.

Operational Test and Evaluation focuses on testing the system in its intended use environment where two primary metrics reign - Operational Effectiveness and Suitability. Operational Effectiveness is the overall degree of mission accomplishment of a system when used by representative personnel in the environment planned or expected for operational employment of the system considering organization, doctrine, survivability, tactics, vulnerability and threat. Operational Suitability is the degree to which a system can be satisfactorily placed in field use, with consideration given to reliability, availability, compatibility, transportability, interoperability, wartime usage rates, maintainability, safety, human factors, manpower supportability, logistics supportability, documentation, training requirements, and natural environmental effects and impacts.

From both Supportability and Supportability Analysis perspectives, DT&E and OT&E combine to provide quantitative measurement and qualitative assessment of both performance in terms of reliability and maintainability, and the effectiveness of the Product Support infrastructure and sustainment resources.

3 CURRICULUM DEVELOPMENT PROCESS

3.1 Proficiency Mapping

The first step in the development process is the mapping of Supportability Analysis proficiencies to the Supportability Analysis Framework as shown in Table 2.
### Table 2 – Supportability Analysis Competency/Proficiency Mapping

The mapping links the Supportability Analysis competency and its proficiencies to the LOG 211 curriculum, which is critical for the certification of the course as “competency-based”. An interesting outcome of this mapping is the identification of the use of analytic tools and techniques and the data basing of Logistics Product Data as underlying tenants of the curriculum.

#### 3.2 Terminal Learning Objectives (TLO)

The second step in the development process is the identification of Terminal Learning Objectives (TLO). The following TLOs were identified and serve to define the course’s topics of instruction:

- Develop Hardware and Software Supportability Objectives and the Maintenance Concept.
- Establish Supportability Metrics.
- Translate metrics into design criteria within SE process.
- Generate Logistics Product Data/GEIA STD-0007 Database.
- Develop R&M Modeling, Prediction, Allocation and Analysis.
- Conduct R&M, Availability, Cost/Affordability Trade-off Analysis.
- Recognize FMECA and FTA processes and contribution to Supportability.
- Recognize value of PHM/RCM in the CBM+ and Supportability processes.
- Conduct Level of Repair Analysis (LORA).
- Conduct Maintenance Task Analysis (MTA).
- Conduct Software Supportability Analysis.
- Recognize the elements of the Product Support Package as an output of Supportability Analysis.
- Recognize the process and impact of Supportability Design Reviews.
- Evaluate suitability in terms of supportability and adequacy of Product Support Package.
- Recognize analytical processes necessary for Post-Fielding Sustainment.
- Generate a Supportability Analysis product (Capstone).

#### 8.3 Delivery Methods

The third step in the development process is the assessment of delivery methods to ensure learning is maximized. The complexity of the LOG 211 Terminal Learning Objectives (TLOs) lead to a decision to use Gaming & Simulation (G&S) and case studies to the greatest extent possible in the discussion of the highly technical areas of Supportability Objectives/Maintenance Concept, Logistics Product Database, R&M Modeling/Trade-Offs, Condition Based Maintenance +, and Level of Repair Analysis. G&S will provide the students with effective tools that provide a wide degree of learning scenarios, learning objectives, factual information and the ability to capture student performance.

#### 8.4 Course Construct

As shown in Table 3, the fourth step in the process is the development of a Course Construct. The Course Construct balances the number and durations of the course topics with the number of day allocated to the course as well as with the methods of delivery.
8.5 Assessment

LOG 211’s assessment strategy is based on the students’ mastery of the competencies and proficiencies as implemented by the Terminal Learning Objectives from which the course content is developed. LOG 211 assessments will be conducted in the form of both graded tests as well as graded performance as evidenced by the correct output of the Gaming and Simulation (G&S) exercises.

REFERENCES


BIOGRAPHY

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Patrick M. Dallosta is the Performance Learning Director for Reliability, Availability, Maintainability & Supportability (RAMS) within the DAU Center for Logistics and Sustainment. He is responsible for ensuring Defense Acquisition Workforce Improvement Act (DAWIA) Life Cycle Logistics (LCL) Career Field competencies, which include Reliability, Availability, Maintainability (RAM) and Supportability, are included in DAU Learning Assets. Prior to joining DAU, Mr. Dallosta served as an Action Officer supporting the Assistant Deputy Under Secretary of Defense for Materiel Readiness (ADUSD/MR). He participated in Systems Engineering Program Support Reviews (PSR) of Major Defense Acquisition Programs to ensure sustainment requirements and supportability considerations were addressed in the design process, and served as a member of the Reliability Improvement Working Group (RIWG). Mr. Dallosta has over thirty years of industry experience in Program Management, Systems Engineering, Reliability Engineering, and Logistics. He holds a Bachelor’s degree in Electrical Engineering from Christian Brothers University, a Master’s in Industrial Engineering from Texas A&M University and is a Candidate for a Master’s in Computer Information Systems. He holds a DAWIA Level III Certification in Life Cycle Logistics, a level II Certification in Requirements Management, and is a SOLE Certified Professional Logistician (CPL).