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SOCIETY FOR MANUFACTURING ENGINEERS

Aerospace and Defense Manufacturing Competency Model—Improving Communication among Employers, Training Providers, and the Workforce

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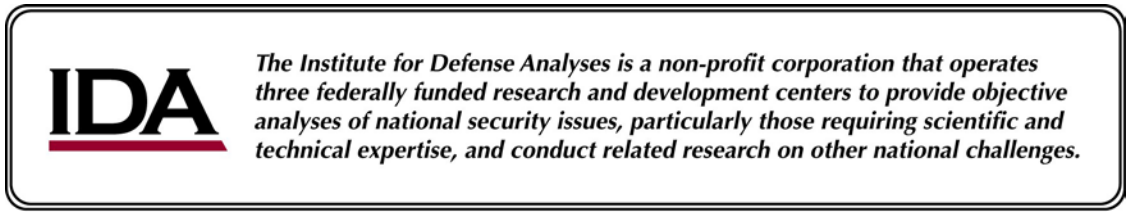

About This Publication

This work was conducted by the Institute for Defense Analyses (IDA) under contract DASW01-04-C-0003, Task AH-6-3461, "Manufacturing Workforce Competency Model," for the Manufacturing Technology (ManTech) Division of the Air Force Research Laboratory and the ManTech Office under the Deputy Assistant Secretary of Defense, Manufacturing & Industrial Base Policy (DASD IP). The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

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Executive Summary

Background and Objective

The study described in this paper was conducted jointly by the Institute for Defense Analyses (IDA) and the Society of Manufacturing Engineers (SME) because of SME's work in the advancement of manufacturing knowledge and workforce skills. This effort was conducted in conjunction with the workforce committee under the National Defense Industrial Association's (NDIA) manufacturing division. It was considered to be one of the workforce committee's projects.

This study identified common manufacturing core competencies for the aerospace and defense (A&D) sector. The resulting aerospace and defense manufacturing competency model (ADMCM) describes the manufacturing community's interface with science and technology, research, design, development, production, and sustainment in a future state consistent with the Manufacturing Readiness Level (MRL) framework. The model reinforces an environment where producibility and manufacturability, design, risk management, and quality systems are fully integrated. The ADMCM is intended to be broadly available to education providers and can be used to implement certification programs, since its competency elements were designed to be objectively measured and assessed.

The impetus for this study is an existing Department of Labor (DOL) advanced manufacturing competency model portrayed as a nine-tiered pyramid.[1] Tiers 1 through 4 are a collection of competency areas and individual competency elements that embody the knowledge, skills, and abilities (KSA) considered necessary for successful performance in manufacturing. Tiers 1 through 3 represent the foundational competencies (Personal Effectiveness, Academic, and Workplace) that apply to all industries engaged in manufacturing. Tier 4 (Industry-Wide Technical Competencies) equates to the cross-cutting technical KSAs required for manufacturing. The DOL effort only populated Tiers 1 through 4; while the remaining tiers, Tiers 5 through 9, are intended to be sector specific.

The ADMCM provides the tiers, competency areas, and competency elements needed to populate Tiers 5 through 9 of the DOL model. The ADMCM applies to both

[1] Employment and Training Administration, *Advanced Manufacturing Competency Model* (Washington, DC: U.S. Department of Labor, April 2010), http://www.careeronestop.org/competencymodel/pyramid.aspx?hg=Y.

the in-house government and private industry workforce throughout the supply chain and can be tailored to a specific job. Competency elements indicate either manufacturing support or lead roles in industry and/or government. The competency elements do not address the proficiencies required for the shop floor workforce (e.g., welders, electricians, etc.).

Model Development

Tiers 5 through 9 were initially populated from competency element development efforts that occurred over the past fifteen years. Subject matter experts were then convened in focus groups to verify the ADMCM. The focus groups included employer and workforce stakeholders from major defense firms who are members of the NDIA or the Aerospace Industries Association (AIA), other A&D manufacturers, and Department of Defense (DOD) acquisition organizations including the Defense Contract Management Agency (DCMA). The Defense Acquisition University (DAU) and the SME also contributed to verification. All of these stakeholders reviewed each ADMCM competency area and element in a facilitated forum. The model was finalized by incorporating the resulting consensus comments into the model.

The strict hierarchical structure of the DOL's pyramid shaped model, which applied to Tiers 1 through 4, does not strictly continue in Tiers 5 through 9. Although Tier 5 (Aerospace and Defense Technical Competencies) and Tier 6 (Facility and Equipment Development) correspond exactly to the DOL model's hierarchical progression, Tier 7 (Planning and Support), Tier 8 (Contracting Support), and Tier 9 (Risk Management) expand beyond the technical manufacturing competencies and are much more inter-dependent.

MRL threads and ADMCM competencies have different, yet related objectives. The objective of assessments of manufacturing readiness is to manage risk and, as a result, the MRL threads represent areas in which to focus manufacturing-related risk management. ADMCM competency areas and elements represent the KSAs desired/needed by the manufacturing workforce. One or more competency areas (and by association competency elements) are required to support the risk assessment areas denoted by each MRL thread. Competency areas are also required to support communities and processes beyond manufacturing-related risk management, e.g., program or financial management.

To increase the utility of the ADMCM, each competency element was augmented by a representative activity for entry-, mid-, and advanced-level individuals. These activities are very similar to the learning or performance objectives training providers use to develop measurable performance outcomes to evaluate the effectiveness of courses.

Value Proposition

Better Buying Power initiatives encourage the implementation of best affordability practices throughout the acquisition, technology, and logistics enterprise to provide greater value to the warfighter. These initiatives began in 2010.[2] Better Buying Power 2.0 established a new focus area, improving the professionalism of the total acquisition workforce.[3] Use of the ADMCM contributes to this effort by helping to relieve two key problems facing the A&D sector today. First, there are an insufficient number of experienced manufacturing personnel in the government's acquisition workforce. This has led to manufacturing issues in programs resulting in increased costs and program delays because producibility was not considered consistently and early in the acquisition life cycle.

Second, companies are having difficulty hiring skilled labor. According to a fall 2011 survey by Deloitte LLP and the Manufacturing Institute, U.S. manufacturers have as many as 600,000 unfilled skilled labor positions. The survey revealed that 67 percent of respondents had a moderate to severe shortage of skilled laborers and 56 percent anticipated that the shortage will worsen in the next three to five years.[4] Furthermore, companies involved in the focus groups indicated that many lower tier suppliers, universities, and colleges do not train/educate students to the full set of core manufacturing competencies.

The ADMCM can convey the benefits of entering the government and industry manufacturing workforce to qualified and motivated individuals and support their career enhancement by contributing to several useful outcomes—a determination of desirable entry-, mid-, and advanced-levels of expertise; a career development path; and a self-paced job advancement plan. The results of this study can also be used by training and certification providers to identify gaps in academic offerings and provide input to fill those gaps. Industry (both prime contractor and lower tier suppliers) can develop more extensive partnerships with colleges and universities. These partnerships can be incubators for new hires by providing the majority of the non-company specific training needed and reduce the cost and/or time required for new hires to be productive.

There are many parallel benefits for government and for industry. The results of this effort will support greater workforce interchangeability and mobility; linking job

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2 Under Secretary of Defense, Acquisition, Technology and Logistics (USD(AT&L)), "Subject: Better Buying Power Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending," memorandum (Washington, DC: Department of Defense, September 14, 2010).

3 USD(AT&L), "Subject: Better Buying Power 2.0: Continuing the Pursuit for Greater Efficiency and Productivity in Defense Spending," memorandum (Washington, DC: Department of Defense, November 13, 2012).

4 William D. Eggers and John Hagel, *Brawn from Brains—Talent, Policy and the Future of American Competitiveness* (Westlake TX: Deloitte University Press, 2012).

descriptions with personnel who have demonstrated the KSAs needed to perform the work; and training and certification programs to facilitate the KSAs needed for job performance, increased efficiency, and improved human capital management.

Next Steps

An extensive series of activities must occur, over a long period of time, before the ADMCM is widely utilized by industry, government, and training and education providers. These activities generally fall into the following categories:

- Making the model known
- Demonstrating the model's value
- Driving middle management to take the actions necessary to ensure its implementation and use

Support from champions is necessary in all of these categories. Leadership is needed to be effective in making the model known and in piloting usage in potential user communities. Furthermore, driving middle management by leading organizations to adopt the model requires proactive support from champions.

Presentations about the model at plenary sessions of large government, industry, and academia sponsored events, such as those organized by NDIA, SME, and AIA, can promote ADMCM awareness. Linkages to existing industry/academia/government partnerships can be developed. There are also opportunities for outreach directly to government initiatives. For example, the Office of the Secretary of Defense's (OSD) Science, Technology, Engineering and Mathematics (STEM) office supports the development of STEM talent in the United States. The DOL could include the ADMCM on its website. In addition, writing articles for well-known publications and having the NDIA publish an independent paper recognizing and recommending the ADMCM would help with outreach.

A key enabling activity for demonstrating the model's effectiveness is teaching its competencies in Defense Acquisition University (DAU) and Air Force Institute of Technology (AFIT) courses. Current offerings could be examined to determine which competency elements are already included in courses. Gaps could then be identified, new learning objectives created, and new course material developed. Special certifications could be developed for Tiers 7, 8, and 9 as they relate to manufacturing. Short courses on any subset of the material in the model could be developed to provide students with salient points and identify sources of additional information. Linkages to MRL Working Group in-process activities to develop an implementation guide and a hotlink knowledge tool that provides greater detail for the MRL maturity matrix elements would correlate closely with and therefore contribute to certifications and short courses by providing the

associated body of knowledge (BoK). Knowledge of certain competency elements could then be established as a requirement for certain positions.

Interfaces with industry/academia/government partnerships as well as the aforementioned outreach activities might help proliferate model usage as a first step in demonstrating the model's effectiveness. A complementary approach could use DOD's assessments of manufacturing readiness to incentivize industry to begin the process of adopting the model. DOD could increase emphasis on the workforce thread by using the ADMCM as a benchmark for these assessments, not only with the prime contractor but also throughout the supply chain. Since industry would be anxious to perform well on the assessments, companies could begin to use the model internally as well as encourage their suppliers to do the same. Eventually, educational partners of prime contractors and lower tier suppliers could alter their courses to reflect the model's competency elements. Furthermore, adoption of the model by higher education providers could drive curriculum changes at the high school level that would encourage more students to enter the A&D manufacturing sector.

To be effective, the above ideas should not be approached in an ad hoc manner. A formal ADMCM strategic implementation plan should be developed taking similar deployment efforts into account to ensure that no opportunities are overlooked. In addition, a business case analysis should be conducted and metrics should be identified to form a basis for measuring progress. Finally, a process should be established for revising the approach when needed.

Contents

Appendices

1. Introduction

A. Research Partners

The study described in this paper was conducted jointly by the Institute for Defense Analyses (IDA) and the Society of Manufacturing Engineers (SME).[1] SME's mission is "to acquire and distribute manufacturing knowledge among its members and the broader manufacturing community."[2]

In addition, this effort was conducted in conjunction with the workforce committee under the National Defense Industrial Association's (NDIA) manufacturing division. It was considered to be one of the workforce committee's projects.

B. Background

The Department of Labor (DOL) developed an advanced manufacturing competency model (AMCM)[3] where competency was defined as:

> A cluster of related knowledge, skills, and abilities that affects a major part of one's job (a role or responsibility), that correlates with performance on the job, that can be measured against well-accepted standards, and that can be improved via training and development.[4]

Characteristics of a competency model are described in references from a DOL sponsored website.

> A competency model is a collection of competencies that together define successful performance in a particular work setting. Competency models are the foundation for important human resource functions such as recruitment and hiring, training and development, and performance management. Competency models can be developed for specific jobs, job groups, organizations, occupations, or industries.[5]

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1 The Society of Manufacturing Engineers website is at http://www.sme.org/.

2 Ibid.

3 Advanced manufacturing is commonly used to represent the cutting edge. The DOL model is more closely aligned with conventional manufacturing.

4 Employment and Training Administration, *Advanced Manufacturing Competency Model* (Washington, DC: U.S. Department of Labor, April 2010), http://www.careeronestop.org/competencymodel/pyramid.aspx?hg=Y.

5 "Develop a Competency Model," *Competency Model Clearinghouse*, careeronestop website, accessed April 19, 2012, www.careeronestop.org/ComptencyModel/userguide_competency.aspx.

Competency models generally include:[6]

- Competency names and detailed definitions
- Descriptions of activities or behavior
- A diagram of the model

The DOL model is portrayed as the nine-tiered pyramid shown in Figure 1. Tiers 1 through 4 are a collection of competency areas represented by blocks on the pyramid. The competency elements for each of these four tiers embody a list of knowledge, skills, and abilities (KSA) considered necessary for successful performance in manufacturing.

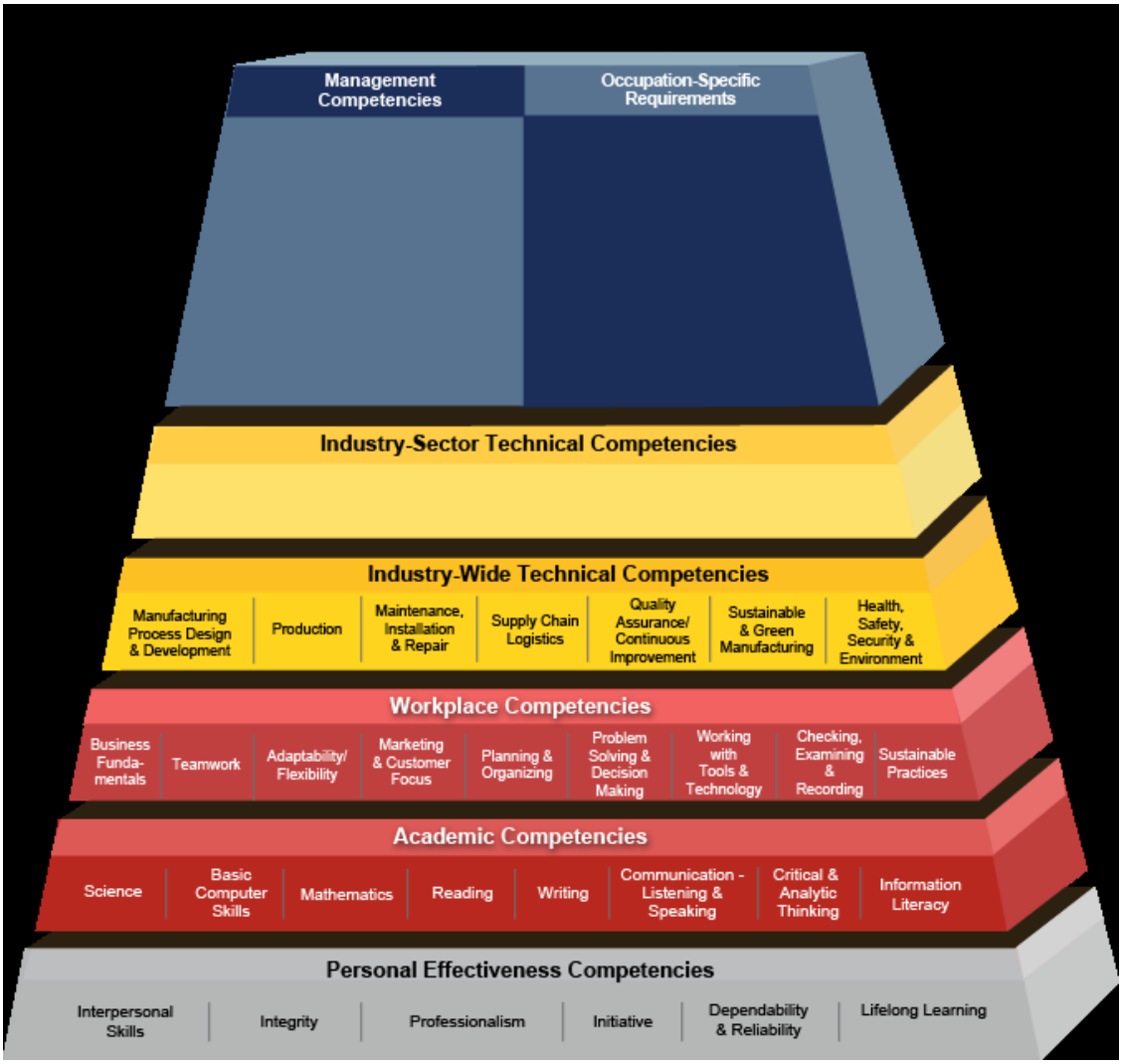

Figure 1. DOL's Advanced Manufacturing Competency Model

6 Ibid.

Tiers 1 through 3 represent the foundational competencies that apply to all industries engaged in manufacturing. They consist of:

- Personal Effectiveness competencies,
- Academic competencies, and
- Workplace competencies.

Tier 4, industry-wide technical competencies, equates to the cross-cutting technical KSAs required for manufacturing. The DOL model provides greater detail (to include critical work functions and technical content areas for both entry-level and technician-level practitioners) for the Tier 4 competency areas. The DOL effort only populated Tiers 1 through 4. The remaining tiers, Tiers 5 through 9, are intended to be sector specific; the associated competency areas have not previously been defined.

C. Objective

This study identified common manufacturing core competencies for the aerospace and defense (A&D) sector. The resulting aerospace and defense manufacturing competency model (ADMCM) describes the manufacturing community's interface with science and technology, research, design, development, production, and sustainment in a future state consistent with the Manufacturing Readiness Level (MRL) framework.[7] The model reinforces an environment where producibility and manufacturability, design, risk management, and quality systems are fully integrated. The ADMCM is intended to be broadly available to education providers and can be used to implement certification programs, therefore its competency elements were designed to be objectively measured and assessed.

This ADMCM identifies the tiers, competency areas, and competency elements needed to populate Tiers 5 through 9 of the DOL model. The ADMCM applies to both the in-house government and private industry workforce throughout the supply chain and can be tailored to a specific job. Competency elements include both manufacturing support and lead roles in industry and/or government. The competency elements do not address those proficiencies required for the shop floor workforce (e.g., welders, electricians, etc.).

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[7] See Department of Defense (DOD), *Manufacturing Readiness Level (MRL) Deskbook*, v2.2 (Washington, DC: DOD), July 2012 at http://dodmrl.org/.

2. Model Development

A. Initial Development and Verification

In 2010 the functional leader for the Production, Quality, and Manufacturing (PQM) acquisition career field for the Department of Defense (DOD), with advice and support from the chair and members of the PQM Functional Integrated Product Team (FIPT), began developing a new competency model for the PQM workforce. A nearly complete draft competency model was produced although the work was never finalized.

A workforce subcommittee, formed by an NDIA Joint Committee on Systems Engineering and Manufacturing, modified the DOD draft competency model. This subcommittee incorporated the key KSAs needed in the DOD workforce to drive the execution of manufacturability and producibility activities earlier in the acquisition process.[8]

The initial work of the current study leveraged the previous work performed by the PQM functional leader and FIPT, NDIA, and a manufacturing and quality assurance document produced by the Air Force to identify potential competency areas and elements necessary to populate Tiers 5 through 9 of the ADMCM. For example,

- The draft competency model work of the PQM functional leader and FIPT and NDIA were compared to DOL's model.
- Additional competency elements were extracted from an Air Force document focused on providing guidance to individuals assigned to the manufacturing/quality function or other functional disciplines involved with manufacturing or quality issues.[9] The document identifies and describes manufacturing and quality assurance activities. For some of the most critical processes, the document includes the purpose, roles and responsibilities, key steps, available tools, and lessons learned from functional experts.

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8 Jay Mandelbaum, Rachel D. Dubin, Margaret C. Hebner, and Lucas A. LaViolet, *Effects of Recent Manufacturing Policy Changes on the Acquisition Workforce*, IDA Paper P-4584 (Alexandria, VA: Institute for Defense Analyses, May 2010).

9 Air Force Aeronautical Systems Command, *Manufacturing and Quality Assurance Acquisition Process Guide* (Wright-Patterson Air Force Base, OH: U.S. Air Force, September 1, 2011).

The competency elements identified through the review of those materials were then grouped into competency areas and ADMCM tiers using affinity diagrams. The ADMCM tiers and competency areas and elements were further refined using material captured in DOL's Aerospace Industry Competency Model[10] (AICM), which contains the following material not included in Tiers 1 through 4 of the DOL model:

- Tier 2, Academic Competencies, includes an Engineering and Technology competency area.
- Tier 3, Workplace Competencies, includes an Innovation and Invention competency area that contains much more information than the Adaptability/Flexibility competency area in Tier 3 of the ADMCM.
- Tier 4, Industry-Wide Technical Competencies, includes three competency areas not found in Tier 4 of the ADMCM—Aerospace Fundamentals, Design and Development, and Aviation Maintenance. These three competency areas were modified and incorporated into Tier 5 of the ADMCM. The remaining three competency areas in Tier 4 of the AICM—Products and Parts Manufacturing, Project Management and Quality Assurance, and Environmental Safety and Health—have analogs in Tier 4 (and Tier 7 for Project Management) of the ADMCM. For these three areas, some elements of the AICM can be used to enrich the ADMCM.

A series of both unpublished and published Army documents[11] were considered as a basis for additional modifications. These documents focused on quality engineering, but their level of granularity was too fine to make changes to Tiers 5 through 9 of the ADMCM.

The Secretary of Defense report to Congress[12] of April 1, 1998, identified and described an urgent need to transition the workforce to meet the needs of a future acquisition environment. One of the studies launched as a result of that report determined the competencies that the workforce will need to operate successfully in the future

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10 Employment and Training Administration, Aerospace Industry Competency Model, U.S. Department of Labor, http://www.careeronestop.org/competencymodel/pyramid.aspx?AEO=Y

11 Aviation and Missile Research, Development and Engineering Center (AMRDEC), *AMRDEC Quality Engineering Division Knowledge, Skills, and Abilities Survey*, draft (Redstone Arsenal, AL: U.S. Army, December 13, 2006). AMRDEC, *KSA Groupings* (Redstone Arsenal, AL: U.S. Army, March 26, 2012). Quality Engineering (QE) Division, *QE Program Activity Assessment Results* (Redstone Arsenal, AL: U.S. Army, April 21, 2010). AMRDEC, *Results Summary Spreadsheet* (Redstone Arsenal, AL: U.S. Army, n.d.); AMRDEC, *Survey KSA Spreadsheet*, version 4 (Redstone Arsenal, AL: U.S. Army, n.d.); and Mike Whitt, *Gap Status* (Redstone Arsenal, AL: U.S. Army, July 2008).

12 William J. Cohen, *Secretary of Defense Report to Congress: Actions to Accelerate the Movement to the New Workforce Vision* (Washington, DC: DOD, April 1, 1998).

environment. The results of that study[13] were also used to make additional refinements to the ADMCM competency elements in the current study.

Consideration was also given to research on advanced manufacturing. A recent IDA paper that synthesized many published definitions of advanced manufacturing concluded that the process involves elements of advanced products, advanced processes and technologies, and/or smart manufacturing and enterprise concepts. That paper adopted the following definition:

> Advanced manufacturing improves existing or creates entirely new materials, products, and processes via the use of science, engineering, and information technologies; high-precision tools and methods; a high-performance workforce; and innovative business or organizational models.[14]

The study also identified five large-scale trends instrumental in the shift to advanced manufacturing processes:

- The ubiquitous role of information technology
- The reliance on modeling and simulation (M&S)
- The acceleration of innovation in global supply-chain management
- Rapid changeability in response to customer needs and external impediments
- The acceptance and support of sustainable manufacturing

While these factors are implicitly captured in many ADMCM competency areas, it is important to explicitly include their state-of-the-art aspects during training and certification for those competency elements.

The final set of pre-verification changes to the tiers, competency areas, and competency elements of the model were derived from the SME body of knowledge (BoK).[15] The SME BoK identifies four areas of knowledge required of manufacturing professions:

- Materials and manufacturing processes

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13 Future Acquisition and Technology Workforce Final Report by the Section 912(c) Working Group In support of the initiatives described in the Office of the Secretary of Defense's April 1998 Report to Congress, April 2000.

14 Stephanie S. Scipp, Nayanee Gupta, Bhavya Lal, Justin A. Scott, Christopher L. Weber, Michael S. Finnin, Meredith Blake, Sherrica Newsome, and Samuel Thomas, *Emerging Global Trends in Advanced Manufacturing*, IDA Paper P-4603 (Alexandria, VA: Institute for Defense Analyses, March 2012).

15 Certified Manufacturing Technologist and Certified Manufacturing Engineer Body of Knowledge, August 2010 as supplemented by unpublished modifications, November 4, 2011.

- Product, tooling and assembly engineering
- Manufacturing systems and operations
- Manufacturing competitiveness

There are ten topics within these four areas. Even though the SME BoK represents higher levels of expertise than those portrayed in Tiers 1 through 4, the majority of these topics were already included in Tiers 1 through 4; however several of the ten topics did inform the development of additional competency areas and competency elements for Tiers 5 through 9 of the ADMCM.

Subject matter experts representing industry and government stakeholders were convened for two focus groups on September 5–6, 2012 and September 26, 2012 to verify the ADMCM. Employer and workforce stakeholders included representatives from the major defense firms who are members of the NDIA or the Aerospace Industries Association (AIA), other A&D manufacturers, and DOD acquisition organizations including the Defense Contract Management Agency (DCMA). The Defense Acquisition University (DAU) and the SME also contributed to verification. All of these stakeholders reviewed each ADMCM competency area and element in a facilitated forum. The model was finalized by incorporating the resulting consensus comments into the model.

B. Tier Descriptions

The strict hierarchical structure of a pyramid shape that applied to Tiers 1 through 4 of the DOL model does not strictly continue in Tiers 5 through 9. The DOL construct recognizes this possibility by splitting the top of the pyramid into vertical areas labeled management competencies and occupation-specific competencies.

Tier 5, Aerospace and Defense Technical Competencies, corresponds exactly to the DOL progression. Tier 6, Facility and Equipment Development, also continues that progression. Tiers 7, 8, and 9, however, go beyond the technical manufacturing competencies and are much more inter-dependent:

- Tier 7, Planning and Support
- Tier 8, Contracting Support
- Tier 9, Risk Management

The principal interactions among Tiers 7 through 9 are as follows:

- Risk management is a key consideration in manufacturing planning.
- Contractors are selected, in part, based on how well they manage technical risk in their proposals; contracts are written in a way to reduce technical risk.

- Manufacturing planning and support are implemented within the context of a contracting strategy.

The interactions extend into Tiers 5 and 6. The product realization competencies, including design considerations in Tier 5, are closely linked with the realization of process capability, as established in Tier 6. Both of these tiers also rely on risk management, contracting support, and planning and support (Tiers 7 through 9). Figure 2 is a graphic depicting the upper part of the DOL pyramid and its Tiers 5 through 9 interactions.

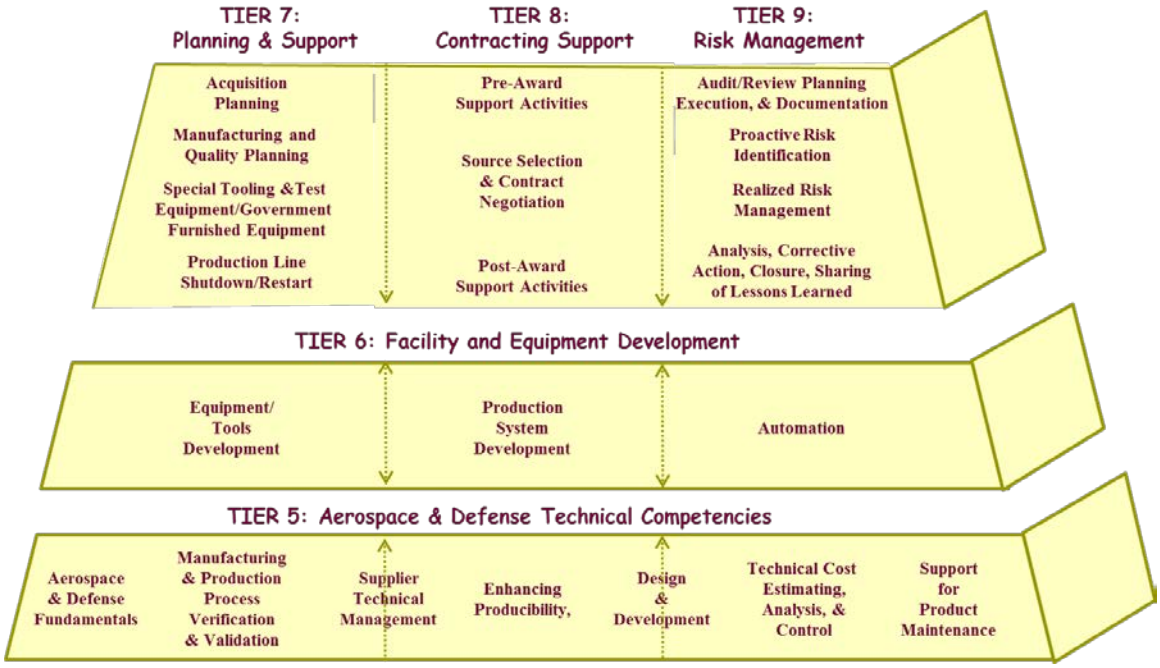

Figure 2. ADMCM Tiers 5 through 9

Per the study's objective, not every ADMCM competency element in Tiers 5 through 9 applies to every job; the model should be tailored to the specific work situation. Competency elements indicate either manufacturing support or lead roles in industry and/or government. Additionally, competency elements were developed under the following conditions:

- The competency element is A&D unique and is not already contained in Tiers 1 through 4.
- The competency element possesses A&D unique aspects but is not A&D unique.
- The competency element is not already contained in Tiers 1 through 4 but is not A&D unique.

The ADMCM does not address the proficiencies required for the shop floor workforce (e.g., welders, electricians, etc.). Also, the competency elements do not apply to the highest level of job advancement where a manufacturing practitioner progresses to a senior management or senior technical position (often termed senior leader in DOD or fellow in industry).

MRL threads and ADMCM competencies have different, yet related objectives. The objective of assessments of manufacturing readiness is to manage risk and, as such, the MRL threads represent areas in which to focus manufacturing-related risk management. ADMCM competency areas and elements represent the KSAs desired/needed by the manufacturing workforce. One or more competency areas (and by association competency elements) are required to support the risk assessment areas denoted by each MRL thread. Competency areas are, however, also required to support communities and processes beyond manufacturing-related risk management, e.g., program or financial management.

All competency elements have been expressed as a sentence clause. To increase the utility of the ADMCM, each competency element was augmented by a representative activity for entry-, mid-, and advanced-level individuals. These activities are very similar to the learning or performance objectives that training providers use to develop performance outcomes that measure the achievement of the learning objectives in courses. Learning objectives can be cognitive, psychomotive (e.g., build a model or a histogram), or affective (i.e., how the student feels—these may be many years in the making and are much more difficult to determine).

The complete competency model is provided in Appendix A. The following sections provide a high level description of each of the tiers.

1. Tier 5

Tier 5 builds upon the previously developed technical competencies identified in Tiers 1 through 4 of the ADMCM and focuses on those competencies required to realize a product within the A&D sector. The competency areas and elements contained in this A&D technical competencies tier represent the manufacturing-related competencies that an individual new to the industry (whether just out of school or previously employed in a different industry) may not be readily aware of based upon educational background and work experience alone.

This tier consists of seven competency areas. A summary description of each is as follows:

- The Aerospace and Defense Fundamentals competency area establishes the need for familiarity with a number of facets—fundamental concepts; common materials; common manufacturing processes; financial and program

management fundamentals; local, state, federal and international laws, regulations, standards and certification requirements; security requirements; and the importance of intellectual property rights—representing uniqueness or importance to the A&D industry. In addition, this competency area requires the ability to identify key differences and similarities between the A&D sector and other industry sectors.

- The Design and Development competency area highlights competency elements regarding how manufacturing should be involved in and influence the design and development of products or systems within the A&D industry. The involvement of manufacturing in design and development begins in the earliest phases of the life cycle. It assists in ensuring that the design criteria consider manufacturing inputs and ultimately that the design is producible within program life-cycle cost, schedule, and performance constraints.
- The Technical Cost Estimating, Analysis and Control competency area identifies a number of cost estimation- and analysis-related factors. The focus is on how manufacturing can inform cost estimation, cost benefit analysis, evaluating target cost, "should" cost, and design to cost for feasibility for the program, as well as identify and assess potential production program cost drivers and the cost effectiveness of manufacturing the product design.
- The Support for Product Maintenance competency area contains competency elements that describe manufacturing's support role in product maintenance. For example, manufacturing can support planning for routine maintenance checks and the development of repair processes and intervals through collaboration on the modeling of manufacturing and repair with logistics. Manufacturing's involvement in planning for maintenance, manufacturing, and testing can ultimately result in improved maintainability, repair, and re-manufacturing of the product, if necessary.
- The Manufacturing and Production Process Verification and Validation (V&V) competency area addresses the planning and execution of V&V on the manufacturing and production process, as well as the product. Also addressed is the planning and execution of first article inspections and additional inspections and testing, as the result of the need for corrective action or other product improvement.
- The Supplier Technical Management competency area consists of competency elements associated with the KSAs necessary to assess the A&D industrial base and supply chain. Knowledge of the supplier base makes it possible to integrate contractor and supplier resources, recommend whether to make a product in-house or purchase it from a supplier, monitor vendor delivery times to ensure

that they meet program schedules, and identify when additional sources of supply or increases in production capacity may be needed. Manufacturing competencies can also prove beneficial to a program through their ability to assess suppliers, based upon objective evidence, for completeness, dependability, performance, and capability. These assessments of suppliers can be documented in existing contractor performance appraisal systems and databases.

- The Enhancing Producibility competency area identifies a set of competency elements for which manufacturing plays a primary role. These competency elements include developing and implementing a producibility improvement plan, assessing manufacturing-related trades on the basis of producibility and life-cycle cost impacts, evaluating manufacturing process capability assessments, and assessing the manufacturing implications of new technologies in a design.

2. Tier 6

Tier 6 addresses the competencies corresponding to the realization of manufacturing and production equipment and facility processes within the A&D industry. This tier is organized into three competency areas that are closely correlated with the Manufacturing, Process Design and Development and the Production competency areas in Tier 4. A summary description of each is as follows:

- The Equipment/Tooling Development competency area addresses the competency elements associated with selecting, adapting, and, when necessary, designing the equipment, tools, and machines required to meet functional requirements, and ultimately to be able to manufacture the product design. This competency area includes the alignment and integration of tooling within and between companies and the application of appropriate preservation, maintenance, and calibration methods for equipment and tools, as well as the design of the actual production line.

- The Production System Development competency area complements the previous competency area and focuses on determining factory and facility infrastructure and layout, as well as assessing facility capabilities and capacities to meet future needs. As part of this competency area, detailed assembly plans need to be developed and production workflow processes and instructions (what to make and when to make it) documented. Additionally, M&S may be conducted to validate a production line's ability to meet cost, schedule, and performance goals and/or the manufacturing capabilities and production practices of others may be benchmarked to identify areas for improvement.

- The Automation competency area builds on the introduction of process control competency elements contained in Tier 4. This competency area focuses on the use, role, and integration of computer networks and automation to assist in controlling the manufacturing process and data collection/management.

3. Tier 7

Tier 7 is concerned with manufacturing planning and support. If a comprehensive plan is not in place, the cost and schedule risks increase significantly. Planning is of particular importance in the A&D sector, due to the complexity of A&D systems compared to commercial systems.

Underlying any manufacturing plan are the overarching acquisition processes under which the plan operates. Therefore, a competency area for acquisition planning is also included. The manufacturing practitioner must be familiar with policy and guidance for developing and implementing the manufacturing aspects of an acquisition strategy, an acquisition plan, and a life cycle sustainment plan. The DOD Defense Acquisition System Directive and Instructions (5000 series documents) prescribe the governing policy for procurement, system engineering, and funding throughout the life cycle. These documents define what the government must do and, as a consequence, what industry must understand and respond to.

Manufacturing and quality planning is the central competency area in this tier. There are multiple components to this competency area:

- The planning itself encompasses many diverse factors, e.g., from infrastructure to simulation, from security to software, or from lead times to error proofing. Plans include all inputs, processes, outputs, and controls. All plans should have a basis in analysis to be cost effective and efficient. Lean and six sigma are two well-known disciplines to eliminate waste. A benefit cost analysis (BCA) should be used to determine the impact of tradeoffs. The differences between process requirements and program requirements are integral to these tradeoffs.
- There is also a workforce component. Planning is needed to close the gap between the skill set available and the skill set needed based on the technical data package and associated work package for the product. Closing the gap entails training, certification, and human resources processes and considerations. There is also a time-phasing consideration; some skills are needed early in a program, while other skills are needed later in development or in production.
- There is also a manufacturing and quality planning component focused on manufacturing interfaces with other planning activities. The manufacturing community has implementation responsibilities for some aspects of the quality plan, much more so in the A&D sector as indicated by the differences between

International Standardization Organization (ISO) 9001, Aerospace Standard (AS) 9100, and the Missile Defense Agency's (MDA's) Assurance Provisions. Furthermore, the manufacturing community is very concerned with taking and using measurements to assure the plan is effective. For example, process capability, scrap, rework, and repair all affect the cost of poor quality. Manufacturing is in a position to measure these considerations and provide recommendations for mitigating actions. There are similar interfaces with the Test and Evaluation Master Plan (TEMP), Integrated Master Plan (IMP), Integrated Master Schedule (IMS), Systems Engineering Plan (SEP), and Life Cycle Sustainment Plan (LCSP).

- Manufacturing interfaces with other functions also plays a role in manufacturing and quality planning. Manufacturing should be involved in the implementation of changes to minimize the difference between how a product is designed and how it is built. Consequently, there should be a profound understanding of configuration management and the implications of doing it wrong. It impacts lead-times, availabilities, technology refreshment, etc. This becomes even more important because of the lengthy data retention requirements that exist in the A&D sector. Manufacturing should be involved in planning for data recording and digital retention. The manufacturing community also needs an understanding of earned value management.
- The final component is the interface with science and technology development. Process technologies often take longer to mature than product technologies, because many process technologies are not even considered until product technologies reach a certain level of maturity. Product updates can sometimes be on an even faster track. The manufacturing community should play a key role in integrating market surveillance and long range planning for all of these areas. Decisions based on this planning are vital to a company's competitiveness and, therefore, to the company's survival. In the A&D sector the cycle time for technology insertion is usually much longer than in commercial applications.

A third competency area in Tier 7 is concerned with special tooling and test equipment (STTE) and government furnished equipment (GFE). There are substantial differences between the government and industry roles—industry uses and maintains equipment while the government conducts oversight of industry activities. STTE/GFE must be managed and any special requirements (e.g., hazardous material, safety, International Traffic in Arms Regulations (ITAR),) should be taken into account. Industry must ensure that this equipment meets the program's technical and schedule requirements, and therefore an understanding of metrology, reliability, maintenance cycles, etc. is necessary. There may also be lead time issues in terms of having the equipment in place when needed.

The final Tier 7 competency area is production line shutdown/restart. Competency elements in this area encompass planning and knowledge management. Implicit and explicit knowledge from subject matter experts throughout the supply chain must be captured at shutdown and maintained. Nothing can be overlooked. At restart, all processes and procedures must be firmly in place at the prime contractor and its supporting subcontractors.

4. Tier 8

Tier 8 includes contracting support competencies. It is organized into three chronologically related competency areas—pre-award support activities, source selection and contract negotiation, and post-award support activities where "award" is defined as contract signing. There is a high degree of overlap between government and industry competencies.

The pre-award support activities competency area is concerned with both requests for proposals (RFP) and responses to them. First, all parties must have an awareness of the relationships between the acquisition strategy and plan and the RFP. RFPs can then be written in a way that accurately reflects the manufacturing requirements for the current phase of acquisition. Another element of an RFP is the source selection criteria. Manufacturing and its associated functions should be evaluated in source selection. The government writes RFPs for industry; companies write RFPs for suppliers. The manufacturing community must understand what potential customers want and the associated schedule, then articulate the proposed technical solution, including how those requirements will be met throughout the supply chain when responding to an RFP.

Generally, only industry will have competency elements relating to responding to RFPs. The manufacturing community will be heavily involved in proposal preparation. A significant part of that involvement is in developing the data for learning curves that will be used to estimate the price of deliverables. This implies an understanding of the design and a determination of who will make it. As part of proposal evaluation, both the government and industry may use pre-award surveys to verify the technical competence and financial viability of bidders. The manufacturing community should be involved in responding to these surveys.

The second competency area is concerned with activities that take place near the time of the award—source selection and contract negotiation. After identifying the manufacturing-related cost, schedule, and performance risks, it is necessary to evaluate how the seller plans to manage those risks. Ultimately this leads to a quantitative and qualitative assessment of the strengths and weaknesses of the proposal based on objective evidence. This assessment is developed by examining greater and greater levels of detail to determine whether the proposal is aligned with the request. For manufacturing, any reliance on new, unproven processes is an important consideration. Past performance is

also a factor. The entire assessment is then used to evaluate each proposal on the basis of the established source selection criteria.

The manufacturing community can play a significant role in contract negotiations. In the seller role, there is a technical element, per the Truth in Negotiations Act, where supporting evidence may be provided for use in the negotiation process. When these negotiations are on a part by part basis, there must be an understanding of whether untested parts are adequate to meet the requirement and factory to factory and line to line differences in cost. In the buyer role, the manufacturing community should be in a position to understand cost realism, and should cost and how it is calculated to support negotiations. Fact finding is used to determine rates.

Post-award support activities begin with a post-award conference shortly after the contract is signed and continue through the life of the contract. The government often convenes a post-award conference to ensure that the seller has a good understanding of project requirements and how products will be delivered; there is a manufacturing element to that meeting. The manufacturing community has an important role in identifying both explicit and implicit manufacturing-related requirements and deliverables. The implicit requirements are those necessary to ensure that the right things are done. The government will begin the process of understanding how the contractor intends to implement the requirements.

There are a number of competency elements that apply throughout contract execution:

- Multiple funding sources and associated colors of money may be involved in a contract. There are legal restrictions on how different colors of money may be used. The manufacturing community must be aware of these limitations and help put processes in place to ensure money is used for the correct purpose. There may be some ambiguity associated with making producibility improvements.
- The manufacturing community may also be called upon to support contract changes.
- Determining and supporting progress payments and award fee plans may also involve the manufacturing community. The government may use MRLs to determine progress payments or award fees.
- Other contract administration activities may have a manufacturing component. Industry must be in a position to respond to government requirements in this area.

Finally, contract close-out studies often involve the manufacturing community.

5. Tier 9

Tier 9 contains risk management competencies. It is divided into four competency areas. First, because audits (whether internal or external) are somewhat self-contained, audit-related competency elements are grouped together. Audits may be thought of as an examination of the competencies of the organizations being reviewed.

The first competency element in this area is determining the manufacturing-related audit criteria. Subject matter knowledge is necessary for this competency in order to understand the audit scope and organize the audit tasks. Once the criteria are established, team members should be chosen on the basis of their expertise. Participation in audits should not be a routine duty for any single manufacturing practitioner. It is important to rotate auditors to avoid complacency.

The next step is to establish a schedule and to communicate it to the organizations being audited in order to gain customer cooperation and support. Audits are often scheduled periodically depending upon the criticality of the processes and the trusted relationships between the organizations. Another consideration is the sheer quantity of audits. Auditing special processes is especially important. The final two competency elements are conducting the audit and documenting the findings. Data should be collected on passes, fails, and critical, major, and minor discrepancies compared to negotiated standards. This defines how the factory is doing and its overall health, based on objective evidence.

The second competency area is proactive risk identification. This area encompasses the best practices for determining manufacturing related risks so that they can be managed well before problems are actually encountered. Knowledge of key characteristics, process capability, and process control is essential. Competency elements in this area include identifying risks through:

- in-process reviews,
- production readiness reviews and assessments of manufacturing readiness,
- evaluations of sole source or foreign suppliers,
- evaluations of critical suppliers,
- assessing design maturity,
- assessing model-based designs for both products and process flow,
- assessing technology readiness,
- assessing performance against plans,
- identifying metrics and evaluating them against standards,
- benchmarking best practices, and

- assessing compliance against certification criteria.

The next competency area is realized risk management, i.e., addressing risks that have resulted in failures. The manufacturing community should be involved since the underlying problems may be related to manufacturing. The first and second elements in this area are concerned with supporting a failure review board that may need to make an immediate determination to stop production or stop operating something if there is a safety concerned. The third element is supporting failure identification to identify the root causes. This must be done in coordination with customers and in compliance with regulations. Finally, the manufacturing practitioner may be called upon to support the failure reporting and corrective action system.

The final competency area in Tier 9 is the progression of analysis, corrective action, closure, and sharing lessons learned associated with manufacturing-related risks. The first step in analysis is finding the root cause if it is not yet known.[16] Scientific problem solving methods, decision analysis, and risk management tools should then be employed to analyze the situation to determine the severity and the likelihood of occurrence. Potential offsetting approaches and their associated impact and benefit should be identified.

Corrective action uses the output of analysis to prioritize risk mitigation efforts, develop a risk management plan (or a manufacturing maturity plan), and communicate that action plan to all stakeholders. The entire supply chain may be involved. Closure occurs when the root cause of the identified problems is corrected in a way that future problems associated with that situation are prevented.

The final competency element is communicating lessons learned. Failure to communicate is the sole reason why problems that are corrected in one organization reoccur in another organization within the same entity.

[16] The root cause should have been identified in the competency elements for realized risk management.

3. Value Proposition

Better Buying Power initiatives encourage the implementation of best affordability practices throughout the acquisition, technology, and logistics enterprise to provide greater value to the warfighter. These initiatives began in 2010.[17] Better Buying Power 2.0 established a new focus area, improving the professionalism of the total acquisition workforce.[18] Use of the ADMCM will contribute to this effort.

A. The Current Problem

From a DOD acquisition program office perspective, there are an insufficient number of experienced manufacturing personnel in the government's acquisition workforce. This has led to manufacturing issues in programs, resulting in increased costs and program delays, because producibility has not been considered consistently and early in the acquisition life cycle. The following represent a subset of examples showing the results of government workforce issues:

- For Air Force support equipment, 67 percent of field failures were attributed to poor manufacturing processes and twelve of eighteen units were returned from the field within weeks of being upgraded. No statement of work (SOW) requirements for producibility, assessments of manufacturing readiness, or metrics were determined to be root causes.[19]
- The Government Accountability Office (GAO) reviewed twenty-one Space and Missile Defense programs and found quality problems in all of them. They quantified the impacts in some cases. For example, one Air Force satellite experienced a $250M cost impact and twenty-four month launch delay due to

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17 Under Secretary of Defense, Acquisition, Technology and Logistics (USD(AT&L)), "Subject: Better Buying Power Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending," memorandum (Washington, DC: Department of Defense, September 14, 2010).

18 USD(AT&L), "Subject: Better Buying Power 2.0: Continuing the Pursuit for Greater Efficiency and Productivity in Defense Spending," memorandum (Washington, DC: Department of Defense, November 13, 2012).

19 Extracted from material submitted by the U.S. Air Force to support the need for a manufacturing military standard.

bad parts. The GAO report discusses how the elimination of manufacturing and quality standards led to an increase in cost, schedule, and quality problems.[20]

- The GAO reviewed four DOD programs and found that manufacturing problems contributed to growth in cost and delays in the schedule. The GAO report stated that manufacturing was overlooked during early development and proper manufacturing and quality requirements are not placed on the contract.[21]

From an industry perspective, companies are having difficulty hiring skilled labor. According to a fall 2011 survey by Deloitte LLP and the Manufacturing Institute, U.S. manufacturers have as many as 600,000 unfilled skilled labor positions. The survey revealed that 67 percent of respondents had a moderate to severe shortage of skilled laborers and 56 percent anticipate that the shortage will worsen in the next three to five years.[22]

The focus groups used in this study indicated that many large DOD contractors have extensive programs to train and tailor core competencies for their applications and they have cultivated partnerships with a limited number of universities and colleges as a basis for new hires. These companies indicate, however, that many lower tier suppliers and many universities and colleges do not train/educate students to the full set of core manufacturing competencies primarily because lower tier suppliers often do not have enough resources to provide sufficient training. In many small companies, fixed overhead is being allocated to a shrinking pool of direct labor hours. To remain competitive from a labor cost perspective, training is kept to a minimum to reduce overhead cost.

B. How the Aerospace and Defense Manufacturing Competency Model (ADMCM) Can Contribute to Improving the Situation

The ADMCM identifies the foundational and cross-cutting manufacturing-related KSAs necessary to successfully perform activities involving manufacturing and/or manufacturing oversight and supervision. Populating tiers 5 through 9 of the ADMCM for the A&D sector will better position government, industry, and academia to create value through stronger partnerships. Through a mutual understanding of each other's competencies, industry (throughout the entire supply chain) should achieve an improved ability to compete for A&D business. At the same time, government will improve its ability to shape its expectations of prime contractors and their supply chain partners

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20 GAO, *Space and Missile Defense Acquisitions Periodic Assessment Needed to Correct Parts Quality Problems in Major Programs*, GAO-11-404 (Washington, DC: GAO, June 24, 2011).

21 GAO, *DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed*, GAO-10-439 (Washington, DC: GAO, April 22, 2010).

22 William D. Eggers and John Hagel, *Brawn from Brains—Talent, Policy and the Future of American Competitiveness* (Westlake TX: Deloitte University Press, 2012).

through understanding and leveraging their strengths. Together, these actions will enhance the likelihood that the government's expectations will be met. From an industry perspective, this implies better customer satisfaction through improved communication and understanding throughout the supply chain and among divisions of the same company.

The results of ADMCM development convey the benefits of entering the government and industry manufacturing workforce to qualified and motivated individuals and support their career enhancement by contributing to several useful products:

- *A determination of desirable entry-, mid-, and advanced-levels of expertise.* This is a direct result of the way in which the ADMCM is developed. For each competency element, it includes representative activities that each of the three levels should be able to perform.
- *A career development path.* Workforce members can determine the skills that demonstrate improved proficiency in a specific competency and the additional competencies they should develop. It also provides a common language that workers can use to help determine where they best fit in.
- *A self-paced job advancement plan.* Once a career path is established, a workforce member can advance to fill opportunities that require a higher skill level.

As far as training and certification providers are concerned, the results of this effort can be used to identify gaps in academic offerings and provide input to plans for filling those gaps. Industry (both prime contractor and lower tier suppliers) can develop more extensive partnerships with colleges and universities. These partnerships can be incubators for new hires by providing the majority of the non-company specific training needed and reducing the cost and/or time required for new hires to be productive.

There are many parallel benefits for government and for industry. The results of this effort will support:

- *Greater workforce interchangeability and mobility of personnel.* The ability to move personnel within an organization to where they are needed is valuable to both government and industry. The ADMCM can also enable movement between companies. This is of clear benefit to the government because it enables increased competition. Some in industry might consider this to be a competitive disadvantage if all of their competitors have the same manufacturing competencies. To some extent that would be true if there are clear differences in skills among the workforces of distinct companies. However, a much more effective differentiator is the ability to gather data from its manufacturing processes and to make decisions based on that data. Use of the ADMCM can

therefore help drive companies to focus on this more important, distinguishing attribute.

- *Linking job descriptions with personnel who have demonstrated the KSAs needed to perform the work.* While this may not be widely done today by means other than aggregate experience, it is a worthwhile goal. In an industry environment, these linkages can be used to assign personnel with demonstrated qualifications to perform work that require those qualifications. For the government, these linkages imply that the program office will be better able to define technical requirements before they are passed along to the prime and sub-contractors.
- *Training and certification programs to facilitate the KSAs needed for job performance.* Both the government and industry can target in-house programs to fill gaps and establish goals for a training progression.
- *Increased efficiency.* Staffs can be streamlined in government and industry manufacturing facilities and government depots. Similarly, government and industry program offices can better leverage the competencies of their workforce. In addition, staff competencies can be assessed to determine potential areas of weakness and risk associated with these weaknesses can be mitigated.
- *Improved human capital management.* The ADMCM can be used to support career development plans for the workforce. Management will be in a better position to understand the current state of the workforce and then identify what is needed for advancement. The ADMCM can also support putting people in the right job. If human resources is using the same guidelines, workforce expectations also have a greater likelihood of being met. In addition, the ADMCM can inform the recruitment process by more clearly identifying the desirable KSAs for job candidates. As discussed above, this enables new hires to become more productive in a shorter period of time. This area may become more important as defense spending is reduced. Defense companies are dealing with attrition due to workforce aging, skilled personnel leaving because of the slowdown in new business, and a weak inflow of incoming talent.[23]

The ADMCM can help mitigate manufacturing-related acquisition issues that have led to undesirable outcomes in the past. The model can be used to establish a broader, more capable hiring base to reduce industry overhead because less training is needed for new employees to become productive. Furthermore, industry skills can be augmented in

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[23] Zachary Fryer-Biggs, Pierre Tran, and Vago Muradian, "Firms Struggle to Keep Talent in Downturn," *Defense News*, July 15, 2012.

the lower tiers, reducing the need for remediation. Finally, manufacturing risks can be better managed in government and industry by employing people with the right competencies.

There are drawbacks associated with trying to use the ADMCM in source selection to mitigate the former situation.

- The individuals a bidder puts forward in a proposal will not necessarily be the individuals who do the work.
- Trying to specify the use of ADMCM competencies throughout the supply chain is extremely difficult.

The use of the ADMCM should help mitigate the latter situation by establishing a standard for the KSAs required to do the job well.

4. Ideas for ADMCM Use

A. Overall Approach

An extensive series of activities must occur, over a long period of time, before the ADMCM is widely utilized by industry, government, and training and education providers. These activities generally fall into the following categories:

- Making the model known
- Demonstrating the model's value
- Driving middle management to take the actions necessary to ensure its implementation and use

Support from champions is necessary in all of these categories. Leadership is needed to be effective in making the model known and in piloting its usage by potential user communities. Furthermore, driving middle management from leading organizations into adopting the model requires proactive support from champions.

Although the individual competency areas are well known and understood, they have never been linked together in a single model. Consequently, near-term efforts should concentrate on increasing awareness of the ADMCM tenets and showing their value to all stakeholders. The next two sections contain some preliminary ideas for pursuing these two subjects. It is premature to suggest how to drive middle management to action.

B. Increasing the Awareness of the Model

ADMCM awareness can be promoted by providing presentations about the model at plenary sessions of large government, industry, and academia sponsored events such as those organized by NDIA, SME, and AIA. The Defense Manufacturing Conference and the SME Aerodef Manufacturing Exposition and Technical Conference are two such forums.

Linkages can be developed to existing industry/academia/government partnerships:

- In June 2011, the President of the United States launched the Advanced Manufacturing Partnership (AMP) to revitalize American manufacturing. The education and workforce development workstream AMP element is trying "to identify tangible actions that support the availability of a robust supply of

talented individuals to provide the human capital to advanced manufacturing companies in the United States today and in the future."[24]

- The NDIA Manufacturing Division Supply Chain Network Committee is examining how to expand the available pool of U.S. manufacturers for A&D needs.
- The National Center of Defense Manufacturing and Machining's mission is, in part, to collaborate with government, industry, and academic organizations to promote best practices through the development and delivery of training.
- The CDIO (Conceive—Design—Innovate—Operate) Initiative is an educational framework for producing the next generation of engineers. It provides a basis for curriculum planning and outcome-based assessment.

There are also opportunities for outreach directly to ongoing government initiatives. For example, the Office of the Secretary of Defense's (OSD's) Science, Technology, Engineering and Mathematics (STEM) office supports the development of STEM talent in the United States. The DOL could also include the ADMCM on its website where it posts other competency models.

In addition, outreach can be accomplished by writing articles for well-known publications. Two good journal candidates are the SME's *Journal of Manufacturing Systems* and the *Defense AT&L* magazine. The NDIA could also publish an independent paper recognizing and recommending the ADMCM.

C. Demonstrating Model Effectiveness

To demonstrate the ADMCM's value, champions are instrumental in piloting usage of the model. Champions should be identified in influential organizations such as the White House's Office of Science and Technology Policy, OSD's Manufacturing and Industrial Base Policy organization (especially the Manufacturing Technology Office), and OSD's Systems Engineering Office. Ties should be developed with the strategic goals of these organizations.

A key enabling activity for demonstrating ADMCM's effectiveness is teaching its competencies in DAU and Air Force Institute of Technology (AFIT) courses. Current offerings could be examined to determine which competency elements are already included in courses. Gaps could then be identified, new learning objectives created, and new course material developed. Special certifications could be developed for Tiers 7, 8, and 9 as they relate to manufacturing. Short courses on any subset of the material in the

[24] Report of the Advanced Manufacturing Partnership Steering Committee, Annex 3, Education and Workforce Development Workstream Report, July 2012.

model could be developed to provide students with salient points and identify sources of additional information. Linkages to MRL Working Group in-process activities to develop an implementation guide and a hotlink knowledge tool that provides greater detail for the MRL maturity matrix elements would correlate closely with and therefore contribute to certification and short courses by providing the associated BoK. Knowledge of certain competency elements could then be established as a requirement for certain positions.

Industry is key to getting the model used—the first step in demonstrating its effectiveness. As the model is used, industry champions will emerge, cross references to human resources models will be created, and training and education institutions will begin teaching the competency elements to create qualified job candidates for companies using the model. Unfortunately, driving model usage in industry/academia is not clear cut. Without strong government support, industry and academia are unlikely to adopt it since there would be little incentive for changing the status quo. Both interfaces with industry/academia/government partnerships and outreach activities would help proliferate use of the model as the first step in demonstrating the model's effectiveness.

A complementary approach could use DOD's assessments of manufacturing readiness to incentivize industry to begin the process of adopting the model. DOD could increase emphasis on the workforce thread by using the ADMCM as a benchmark for these assessments, not only with the prime contractor but also throughout the supply chain. Since industry would be anxious to perform well on the assessments, they could begin to use the model internally as well as encourage their suppliers to do the same. Eventually, educational partners of prime contractors and lower tier suppliers could alter their courses to reflect the model's competency elements. Furthermore, adoption of the model by higher education providers could drive curriculum changes at the high school level that would encourage more students to enter the A&D manufacturing sector.

D. Conclusions

To be effective, the above ideas should not be approached in an ad hoc manner. A formal ADMCM strategic implementation plan should be developed taking similar deployment efforts into account to ensure that no opportunities are overlooked. In addition, a business case analysis should be conducted and metrics should be identified to form a basis for measuring progress. Finally, a process should be established for revising the approach when needed.

Final proof of model utility should not be on the critical path of its implementation, because such proof would require many years to develop. As long as there are indications of value, implementation should proceed in parallel to measurements of value.

Appendix A
Aerospace and Defense Manufacturing Competency Model

TIER 5. Aerospace and Defense Technical Competencies

1. Aerospace and Defense Fundamentals

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Demonstrating familiarity with and the ability to apply fundamental concepts (i.e., terminology, requirements).	Describe fundamental concepts (i.e., terminology, requirements).	Explain and apply fundamental concepts (i.e., terminology, requirements).	Interpret fundamental concepts (i.e., terminology, requirements) and evaluate their application.
Identifying key differences and similarities between the aerospace and defense (A&D) sector and other industry sectors.	Explain the key differences and similarities between A&D industry sectors.	Distinguish the key differences and similarities between A&D industry sectors.	Assess how key differences and similarities between A&D industry sectors affect manufacturing.
Demonstrating familiarity with the common materials (i.e., properties, uses, machining/processing effects limits) used in the industry.	Identify common materials frequently used in the industry on the basis of their properties, uses, and machining/ processing effects limits.	Analyze the application of common materials frequently used in the industry on the basis of their properties, uses, and machining/processing effects limits.	Evaluate the pros and cons of common materials frequently used in the industry on the basis of their properties, uses, and machining/processing effects limits.
Demonstrating familiarity with the manufacturing processes used in the industry.	Describe the manufacturing processes used in the industry.	Explain the manufacturing processes used in the industry.	Interpret the manufacturing processes used in the industry.
Demonstrating familiarity with the fundamentals of financial and program management.	Describe the fundamentals of financial and program management.	Explain the fundamentals of financial and program management.	Interpret the fundamentals of financial and program management.
Demonstrating familiarity with relevant local, state, federal, and international laws, regulations, standards, and certification requirements (to include export control processes) that impact the sector.	Identify relevant local, state, federal, and international laws, regulations, and certification requirements (to include export control processes) that impact the sector.	Interpret the applicability of local, state, federal, and international laws, regulations, and certification requirements (to include export control processes) that impact the sector.	Evaluate compliance with relevant local, state, federal, and international laws, regulations, and certification requirements (to include export control processes) that impact the sector.
Demonstrating familiarity with security requirements for the sector.	Describe the security requirements for the sector.	Explain the security requirements for the sector.	Interpret the security requirements for the sector.
Demonstrating familiarity with intellectual property rights and avoiding infringement of the intellectual property rights of others.	Describe intellectual property rights considerations.	Determine applicability of intellectual property rights for the design.	Evaluate the need for intellectual property rights protection and agreements to use the intellectual property of others.

2. Design and Development

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Supporting the formulation of a producible conceptual design of products or systems.	Describe the steps in producible conceptual design of products or systems.	Draft the producible conceptual design of products or systems.	Assess and finalize the producible conceptual design of products or systems.
Providing manufacturing input into the development of design criteria for products or systems, including understanding the requirements, testing methods, production costs, quality standards, completion dates, and design for X (e.g., assembly, manufacturing, maintenance, reliability).	Identify potential manufacturing-related design criteria for products or systems, including understanding the requirements, testing methods, production costs, quality standards, completion dates, and design for X (e.g., assembly, manufacturing, maintenance, reliability).	Interpret the applicability of manufacturing-related design criteria for products or systems, including understanding the requirements, testing methods, production costs, quality standards, completion dates, and design for X (e.g., assembly, manufacturing, maintenance, reliability).	Evaluate and finalize manufacturing-related design criteria for products or systems, including understanding the requirements, testing methods, production costs, quality standards, completion dates, and design for X (e.g., assembly, manufacturing, maintenance, reliability).
Evaluating product and design data from inspections and reports for conformance to design criteria, engineering principles, customer requirements, safety, and quality standards.	Recognize how to evaluate product and design data from inspections and reports for conformance to design criteria, engineering principles, customer requirements, safety, and quality standards.	Determine the extent to which product and design data from inspections and reports conform to design criteria, engineering principles, customer requirements, safety, and quality standards.	Assess product and design data from inspections and reports for conformance to design criteria, engineering principles, customer requirements, safety, and quality standards.
Applying computer-aided design/computer-aided manufacturing/computer-aided engineering (CAD/CAM/CAE) principles to product design.	Define CAD/CAM/CAE principles for product design.	Apply CAD/CAM/CAE principles for product design.	Evaluate the use of CAD/CAM/CAE principles for product design.
Supporting the development of new materials and manufacturing technologies (especially "game-changer" technologies).	Describe potential new materials and manufacturing technologies (especially "game-changer" technologies).	Examine the use of new materials and manufacturing technologies (especially "game-changer" technologies).	Evaluate and select new materials and manufacturing technologies (especially "game-changer" technologies).
Developing prototypes of systems and equipment.	Describe the steps to develop prototypes of systems and equipment.	Develop process to produce prototypes of systems and equipment.	Assess and finalize the process for producing prototypes of systems and equipment.
Planning, conducting and reporting on experimental, environmental, operational, and stress tests on models and prototypes of systems and equipment.	Describe experimental, environmental, operational, and stress tests used on models and prototypes of systems and equipment.	Employ experimental, environmental, operational, and stress tests on models and prototypes of systems and equipment.	Evaluate the results of experimental, environmental, operational, and stress tests used on models and prototypes of systems and equipment.
Setting realistic geometric dimensioning and tolerancing (GD&T) requirements taking temperature, climate, and environmental factors into account.	Describe realistic GD&T requirements taking temperature, climate, and environmental factors into account.	Apply realistic GD&T requirements taking temperature, climate, and environmental factors into account.	Assess the use of realistic GD&T requirements taking temperature, climate, and environmental factors into account.

3. Technical Cost Estimating, Analysis, and Control

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Identifying possible production program cost drivers under various circumstances; and managing affordability programs.	Recognize possible production program cost drivers under various circumstances.	Examine possible production program cost drivers under various circumstances; and analyze affordability programs.	Evaluate possible production program cost drivers under various circumstances; and develop and evaluate affordability programs.
Utilizing learning and cost improvement curves in cost estimation. Assessing cost benefit analysis. Assessing the cost effectiveness of manufacturing the product design.	Explain the use of learning and cost improvement curves in cost estimation. Recognize factors to be considered in cost benefit analysis. Recognize elements needed to assess the cost effectiveness of manufacturing the product design.	Apply learning and cost improvement curves in cost estimation. Conduct cost benefit analysis. Appraise the cost effectiveness of manufacturing the product design.	Evaluate learning and cost improvement curves in cost estimation. Assess and revise cost benefit analysis. Assess the cost effectiveness of manufacturing the product design.
Evaluating target cost, "should" cost, and design to cost for feasibility. Modeling current cost estimates and metrics.	Explain the feasibility of target cost, "should" costs, and design to cost. Recognize elements of modeling current cost estimates and metrics.	Analyze target cost, "should" cost, and design to cost for feasibility. Model current cost estimates and metrics.	Evaluate target cost, "should" cost, and design to cost for feasibility. Assess and revise modeling of current cost estimates and metrics.
Analyzing work measurement data and comparing planned work and costs against actual work completed to provide program managers, contracting officers, and others with an objective estimate of program progress and cost to complete.	Explain the use of work measurement data to compare planned work and costs against actual work completed to provide program managers, contracting officers, and others with an objective estimate of program progress and cost to complete.	Apply work measurement data and compare planned work and costs against actual work completed to provide program managers, contracting officers, and others with an objective estimate of program progress and cost to complete.	Evaluate work measurement data and assess planned work and costs against actual work completed to provide program managers, contracting officers, and others with an objective estimate of program progress and cost to complete.
Establishing the value engineering program to ensure effectiveness, reduce costs, and ensure the utilization of new and appropriate technologies.	Define and describe the characteristics and benefits of a value engineering program to ensure effectiveness, reduce costs, and ensure the utilization of new and appropriate technologies.	Employ and analyze a value engineering program to ensure effectiveness, reduce costs, and ensure the utilization of new and appropriate technologies.	Design and evaluate a value engineering program to ensure effectiveness, reduce costs, and ensure the utilization of new and appropriate technologies; revise, as appropriate.

4. Support for Product Maintenance

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Describing possible discrepancies and defects that could affect the safety or mission effectiveness of products.	Identify possible discrepancies and defects that could affect the safety or mission effectiveness of products.	Analyze possible discrepancies and defects that could affect the safety or mission effectiveness of products.	Evaluate possible discrepancies and defects that could affect the safety or mission effectiveness of products.
Supporting the planning for routine maintenance checks (incorporating unscheduled, non-routine tasks) and developing repair processes and intervals through a shared responsibility of modeling manufacturing and repair with logistics.	Describe how manufacturing supports routine maintenance checks (incorporating unscheduled, non-routine tasks); and identify how manufacturing supports development of repair processes and intervals through a shared responsibility of modeling manufacturing and repair with logistics.	Apply manufacturing support to planning routine maintenance checks (incorporating unscheduled, non-routine tasks); and apply manufacturing support to developing repair processes and intervals through a shared responsibility of modeling manufacturing and repair with logistics.	Assess the effectiveness of manufacturing support to planning routine maintenance (incorporating unscheduled, non-routine tasks); and evaluate the effectiveness of manufacturing support to developing repair processes and intervals through a shared responsibility of modeling manufacturing and repair with logistics.
Planning for efficient maintenance, re-manufacturing, and testing procedures (i.e., sampling plans, final testing and assembly) to enhance maintainability, repair, and re-manufacturing.	Describe planning for efficient maintenance, re-manufacturing, and testing procedures (i.e., sampling plans, final testing and assembly) to enhance maintainability, repair, and re-manufacturing.	Conduct planning for efficient maintenance, re-manufacturing, and testing procedures (i.e., sampling plans, final testing and assembly) to enhance maintainability, repair, and re-manufacturing.	Evaluate the effectiveness of planning for efficient maintenance, re-manufacturing, and testing procedures (i.e., sampling plans, final testing and assembly) to enhance maintainability, repair, and re-manufacturing.
Applying inspection procedures and utilizing automated and built in test equipment/features involved in testing (to include systems readiness tests and pre- and post-operational checkouts) aircraft, missile, and other defense systems under simulated operational conditions.	Describe inspection procedures and automated and built in test equipment/features involved in testing (to include systems readiness tests and pre- and post-operational checkouts) aircraft, missile, and other defense systems under simulated operational conditions.	Employ inspection procedures and automated and built in test equipment/features involved in testing (to include systems readiness tests and pre- and post-operational checkouts) aircraft, missile, and other defense systems under simulated operational conditions.	Evaluate the results of inspection procedures and automated and built in test equipment/features involved in testing (to include systems readiness tests and pre- and post-operational checkouts) aircraft, missile, and other defense systems under simulated operational conditions.

5. Manufacturing and Production Process Verification and Validation

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Conducting predictive analysis and modeling and simulation (M&S) of results from equipment tests (to include accelerated testing), inspections, and operational usage to statistically forecast the likelihood and criticality of failures, maintenance requirements, and if the need exists for manufacturing process changes.	Define and describe options for predictive analysis and M&S of results from equipment tests (to include accelerated testing), inspections, and operational usage to statistically forecast the likelihood and criticality of failures, maintenance requirements, and if the need exists for manufacturing process changes.	Apply and analyze predictive analysis and M&S of results from equipment tests (to include accelerated testing), inspections, and operational usage to statistically forecast the likelihood and criticality of failures, maintenance requirements, and if the need exists for manufacturing process changes.	Design approach for and evaluate predictive analysis and M&S of results from equipment tests (to include accelerated testing), inspections, and operational usage to statistically forecast the likelihood and criticality of failures, maintenance requirements, and if the need exists for manufacturing process changes.
Planning and executing process verification and validation (V&V), to include techniques such as the use of predictive analysis and modeling and simulation.	Describe process V&V, to include techniques such as the use of predictive analysis and M&S.	Employ and analyze process V&V, to include techniques such as the use of predictive analysis and M&S.	Formulate and evaluate the effectiveness of process V&V, to include techniques such as the use of predictive analysis and M&S.
Planning and executing first article inspections and additional inspections and testing associated with corrective action or product improvement.	Describe first article inspections and additional inspections and testing associated with corrective action or product improvement.	Employ and analyze first article inspections and additional inspections and testing associated with corrective action or product improvement.	Formulate approach for first article inspections and additional inspections and testing associated with corrective action or product improvement.

6. Supplier Technical Management

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Conducting industrial base assessments.	Describe the importance of conducting industrial base assessments.	Conduct less complex industrial base assessments.	Conduct complex industrial base assessments.
Determining whether it is more appropriate to make a product in-house or purchase it from a supplier.	Identify criteria for determining whether it is more appropriate to make a product in-house or purchase it from a supplier.	Analyze and suggest whether it is more appropriate to make a product in-house or purchase it from a supplier.	Evaluate and approve the analysis for determining whether it is more appropriate to make a product in-house or purchase it from a supplier.
Demonstrating cognizance of vendor delivery times to ensure supply availability.	Record and report vendor delivery times to ensure supply availability.	Schedule and calculate vendor delivery times to ensure supply availability.	Arrange for, evaluate, and revise vendor delivery times to ensure supply availability.
Demonstrating familiarity with and providing inputs to contractor performance appraisal systems and databases.	Describe the inputs associated with contractor performance appraisal systems and databases.	Use contractor appraisal systems and databases.	Evaluate and revise contractor performance ratings using appraisal systems and databases.
Assessing the supplier base, based upon objective evidence, for completeness, dependability, performance, and supplier capability (to include whether suppliers have the capacity to meet delivery and production schedules throughout the life cycle).	Describe how objective evidence is used for assessing the supplier base, based completeness, dependability, performance, and supplier capability (to include whether suppliers have the capacity to meet delivery and production schedules throughout the life cycle).	Apply objective evidence to examine the supplier base, based on completeness, dependability, performance, and supplier capability (to include whether suppliers have the capacity to meet delivery and production schedules throughout the life cycle).	Evaluate how objective evidence is used to assess the supplier base, based on completeness, dependability, performance, and supplier capability (to include whether suppliers have the capacity to meet delivery and production schedules throughout the life cycle).
Optimizing the integration of contractor and supplier capabilities.	Identify characteristics to optimize the integration of contractor and supplier capabilities.	Integrate contractor and supplier capabilities.	Evaluate whether the integration of contractor and supplier capabilities is optimized; and revise, as needed.
Responding to need for additional sources of supply and/or increases in required production capacity to satisfy spare and repair parts requirements.	Define and describe the need for additional sources of supply and/or increases in required production capacity to satisfy spare and repair parts requirements.	Interpret and analyze the need for additional sources of supply and/or increases in required production capacity to satisfy spare and repair parts requirements.	Evaluate and revise the response to the need for additional sources of supply and/or increase in required production capacity to satisfy spare and repair parts requirements.
Validating whether technical data used by procurement is complete, accurate, and captures current and future requirements.	List and report technical data used by procurement for its completeness, accuracy, and whether it captures current and future requirements.	Interpret and analyze technical data used by for its completeness, accuracy, and whether it captures current and future requirements.	Assess whether technical data used by procurement is complete, accurate, and captures current and future requirements; revise, as appropriate.
Mitigating diminishing manufacturing sources and material shortages (DMSMS); validating obsolescence management programs to identify components or technologies likely to become obsolete, unavailable, or expensive during the life of a program, and identifying alternatives to satisfy program requirements to prevent an impact on production.	Define DMSMS, describe its impact on a program, and explain mitigation strategies.	Use DMSMS management processes to identify 1) components or technologies likely to become obsolete, unavailable, or expensive during the life of a program, and 2) alternatives to satisfy program requirements to prevent an impact on production; analyze the results.	Design DMSMS management processes to identify 1) components or technologies likely to become obsolete, unavailable, or expensive during the life of a program, and 2) alternatives to satisfy program requirements to prevent an impact on production; evaluate the results.

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Developing effective measures to avoid the use of unqualified parts.	Define and describe effective measures to avoid the use of unqualified parts.	Apply and analyze measures to avoid the use of unqualified parts.	Develop and assess measures to avoid the use of unqualified parts.

7. Enhancing Producibility

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Developing a producibility improvement plan to mitigate risks and assessing and assuring producibility (according to the plan) early in the life cycle.	Define and describe elements of a producibility improvement plan to mitigate risks.	Employ the producibility improvement plan to mitigate risks; and analyze producibility (according to the plan) early in the life cycle.	Design the producibility improvement plan to mitigate risks; and assess and evaluate producibility (according to the plan) early in the life cycle.
Assessing manufacturing-related design trades on the basis of producibility and life-cycle cost impacts.	Recognize the characteristics of manufacturing-related design trades.	Analyze manufacturing-related design trades on the basis of producibility and life-cycle cost impacts.	Formulate and assess manufacturing-related design trades on the basis of producibility and life-cycle cost impacts.
Managing and evaluating manufacturing process capability assessments.	Recognize the factors to be considered in a manufacturing process capability assessment.	Employ and examine the approach for evaluating manufacturing process capability assessments.	Evaluate manufacturing process capability assessments.
Reading, interpreting, and assessing technical data to assess the manufacturing implications of new technologies in the design.	Define and describe the implications of technical data in assessing the manufacturing implications of new technologies in the design.	Interpret and analyze the implications of technical data in assessing the manufacturing implications of new technologies in the design.	Evaluate how technical data is used to assess manufacturing implications of new technologies in the design; revise as required.

TIER 6. Facility and Equipment Development

1. Equipment/Tools Development

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Selecting, optimizing, and, when necessary, designing cutting tools, work holding tools, die/molds, and gages to meet functional requirements; determining operating guidelines; and testing whether requirements are met.	Recognize considerations for selecting, optimizing, and, when necessary, designing cutting tools, work holding tools, die/molds, and gages to meet functional requirements; describe operating guidelines; and describe tests to determine whether requirements are met.	Select, optimize, and, when necessary, design cutting tools, work holding tools, die/molds, and gages to meet functional requirements; determine operating guidelines; and test whether requirements are met.	Evaluate the results of the selection, optimization, and, when necessary, design of cutting tools, work holding tools, die/molds, and gages to meet functional requirements; evaluate the effectiveness of operating guidelines; and evaluate how to satisfy requirements that are not met.
Adapting, selecting, and/or designing machines to meet functional requirements, determining operating guidelines, and testing whether requirements are met.	Recognize considerations for adapting, selecting, and/or designing machines to meet functional requirements; describe operating guidelines; and describe tests to determine whether requirements are met.	Adapt, select, and/or design machines to meet functional requirements; determine operating guidelines; and test whether requirements are met.	Evaluate the results of the adaptation, selection, and/or design of machines to meet functional requirements; evaluate the effectiveness of operating guidelines; and evaluate how to satisfy requirements that are not met.
Researching and applying appropriate preservation, maintenance, and calibration methods for equipment and tools.	Identify possible preservation, maintenance, and calibration methods for equipment and tools.	Select and employ appropriate preservation, maintenance, and calibration methods for equipment and tools.	Assess the effectiveness of preservation, maintenance, and calibration methods for equipment and tools.
Aligning and integrating tooling within and between suppliers/subcontractors.	Describe methods for aligning and integrating tooling within and between suppliers/subcontractors.	Employ methods for aligning and integrating tooling within and between suppliers/subcontractors.	Evaluate the effectiveness of methods for aligning and integrating tooling within and between suppliers/subcontractors; revise, as necessary.

2. Production System Development

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Determining factory infrastructure (facility or production) requirements for power, water, heating, ventilation, and air conditioning, etc. and analyzing the business case concerning options for facility location.	Describe facility infrastructure requirements for power, water, heating, ventilation, and air conditioning, etc.	Interpret the implications of facility infrastructure requirements for power, water, heating, ventilation, and air conditioning, etc. through a business case analysis of facility location options.	Evaluate facility location options based upon facility infrastructure requirements for power, water, heating, ventilation, and air conditioning, etc.
Determining facility layout requirements (based upon an interpretation of product specifications) and analyzing alternatives to meet those requirements.	Describe considerations for the layout of facilities (based upon an interpretation of product specifications).	Interpret the pros and cons of alternative facility layouts (based upon an interpretation of product specifications).	Evaluate alternative facility layouts (based upon an interpretation of product specifications) to meet requirements; and revise, as necessary.
Analyzing and assessing facility capabilities and capacities, comparing them to future needs, and suggesting options to close the gap.	Describe considerations for comparing facility capabilities and capacities to future needs.	Employ process to compare facility capabilities and capacities to future needs and illustrate options to close the gap.	Assess facility capabilities capacities compared to future needs and evaluate options to close the gap.
Creating detailed assembly plans, including sequencing and identifying tooling, fixtures and equipment needs.	Describe considerations (i.e., sequencing and identifying tooling, fixtures and equipment needs) for detailed assembly plans.	Develop detailed assembly plans, including sequencing and identifying tooling, fixtures and equipment needs.	Evaluate detailed assembly plans, including sequencing and identifying tooling, fixtures, and equipment needs; and revise, as appropriate.
Benchmarking manufacturing capabilities and suggesting production practices, manufacturing system designs, and organizational changes to close the gap.	Describe considerations for benchmarking manufacturing capabilities and suggesting production practices, manufacturing system designs, and organizational changes to close the gap.	Employ benchmarking manufacturing capabilities and interpret production practices, manufacturing system designs, and organizational changes to close the gap.	Assess benchmarking capabilities and evaluate production practices, manufacturing system designs, and organizational changes to close the gap.
Developing and documenting work flow processes and instructions.	Explain work flow processes and instructions.	Employ work flow processes and instructions.	Evaluate and approve workflow processes and instructions.
Modeling and validating the ability of a production line to meet cost, schedule, and performance goals.	Explain how to model and validate the ability of a production line to meet cost, schedule, and performance goals.	Employ modeling and validating techniques to illustrate the ability of a production line to meet cost, schedule, and performance goals.	Assess the results of modeling and validating the ability of a production line to meet cost, schedule, and performance goals.
Designing a production line.	Identify the characteristics of a production line.	Develop the preliminary design for a production line.	Finalize a production line design and evaluate its effectiveness.
Ensuring that the manufacturing and production line processes meet safety requirements by considering human factors, ergonomics, and other criteria contributing to hazards.	Describe how the consideration of human factors, ergonomics, and other criteria contributing to hazards are used to determine whether manufacturing and production line processes meet safety requirements.	Analyze the extent to which the manufacturing and production line processes achieve safety requirements by considering human factors, ergonomics, and other criteria contributing to hazards.	Evaluate the results of analyses regarding the extent to which the manufacturing and production line processes achieve safety requirements by considering human factor, ergonomics, and other criteria contributing to hazards; and revise, as necessary.
Managing waste in an environmentally sound manner (taking into account sustainability, timing, and recycling).	Describe considerations for managing waste.	Develop a process for managing waste in an environmentally sound manner.	Evaluate the environmental effects of waste management processes and procedures; and revise, as necessary.

3. Automation

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Establishing requirements for automation and determining whether tooling should be hard, flexible, or soft.	Describe considerations for automation requirements and determining whether tooling should be hard, flexible, or soft.	Analyze alternatives to meet requirements for automation and determine whether tooling should be hard, flexible, or soft.	Evaluate the effectiveness of alternatives to meet requirements for automation and assess whether tooling should be hard, flexible, or soft.
Determining the role and use of computer networks in establishing control over the manufacturing process.	Describe considerations for the role and use of computer networks in establishing control over the manufacturing process.	Develop processes to use computer networks in establishing control over the manufacturing process.	Assess the effectiveness of using computer networks in establishing control over the manufacturing process.
Managing the use of enterprise-wide systems integration (to include the role and use of information technology and data bases) as it relates to manufacturing process control and data collection/management (to include by automation).	Describe considerations for the use of enterprise-wide systems integration (to include the role and use of information technology and data bases) as it relates to manufacturing process control and data collection/management (to include by automation).	Analyze how to use enterprise-wide systems integration (to include the role and use of information technology and data bases) as it relates to manufacturing process control and data collection/management (to include by automation).	Assess the effectiveness of enterprise-wide systems integration (to include the role and use of information technology and data bases) as it relates to manufacturing process control and data collection/management (to include by automation).

TIER 7. Acquisition Planning and Support

1. Acquisition Planning

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Developing an acquisition strategy and plan that are consistent with the Department of Defense (DOD) Acquisition System (5000 series and Defense Acquisition Guidebook) and key milestones as they relate to production, quality, and manufacturing (PQM) functions.	Recognize PQM-related elements of an acquisition strategy and plan that are consistent with the DOD Acquisition System (5000 series and Defense Acquisition Guidebook) and key milestones, as they relate to PQM functions in an acquisition plan.	Interpret the PQM-related elements of an acquisition strategy and plan that are consistent with the DOD Acquisition System (5000 series and Defense Acquisition Guidebook) and key milestones, as they relate to PQM functions in an acquisition plan.	Evaluate program's adherence to PQM-related elements of the acquisition strategy and plan, consistent with the DOD Acquisition System (5000 series and Defense Acquisition Guidebook) and key milestones, as they relate to PQM functions in an acquisition plan; and revise those elements of the plan, as appropriate.
Developing the PQM aspects of a life cycle sustainment plan consistent with how systems evolve from mission needs through development and production to deployment and disposal.	Recognize PQM-related aspect of a life cycle sustainment plan consistent with how systems evolve from mission needs through development and production to deployment and disposal.	Interpret and examine whether the PQM-related aspects of a life cycle sustainment plan are consistent with how the system is evolving from mission needs through development and production to deployment and disposal.	Evaluate/revise the PQM-related aspects of life cycle sustainment plan to determine the degree to which they are consistent with the system's evolution from mission needs through development and production to deployment and disposal; revise the plan as necessary.

2. Manufacturing and Quality Planning

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Developing a manufacturing plan and associated resource needs for the program.	Describe the elements of a manufacturing plan and associated resource needs for the program.	Develop and apply the manufacturing plan, which includes associated resource needs for the program.	Evaluate the manufacturing plan to include associated resource needs for the program; and revise, as necessary.
Developing manufacturing plans and actions based on a business case analysis determination of a return on investment.	Explain elements of a business case analysis associated with manufacturing plans.	Develop a business case analysis for justifying manufacturing plans and actions.	Assess the results of a business case analysis for justifying manufacturing plans and actions.
Assessing and validating workforce size, workforce skill levels, training requirements, and maintaining timely and efficient responses to hiring needs to ensure successful production and quality management.	Describe considerations for determining workforce size, workforce skill levels, and training requirements to maintain a timely and efficient response to hiring needs for successful production and quality management.	Interpret and examine workforce size, workforce skill levels, and training requirements to maintain a timely and efficient response to hiring needs to ensure successful production and quality management.	Evaluate workforce size, workforce skill levels, and training requirements to maintain a timely and efficient response to hiring needs to ensure successful production and quality management; make adjustments as required.
Assessing the skill set required for a project and how personnel might develop the requisite skills.	Describe the skill set required for a project and how personnel management might develop the requisite skills.	Interpret and analyze the skill set required for a project and how personnel might develop the requisite skills.	Assess the skill set required for a project and how personnel might develop the requisite skills; make adjustments as required.
Assessing actions taken to implement configuration management programs as a function of program phase.	Explain the implementation of configuration management as a function of program phase.	Analyze the actions taken to implement configuration management as a function of program phase.	Assess and revise actions taken to implement configuration management as a function of program phase.
Recording and maintaining requisite data	Describe the requisite data to be recorded and maintained.	Determine and capture the requisite data that needs to be recorded and maintained.	Assess the effectiveness of the process for recording and maintaining the requisite data.
Documenting the manufacturing elements of a quality strategy and plan in accordance with AS9100 or higher level standard	Describe the elements of a quality strategy and plan in accordance with AS 9100 or higher level standard.	Apply the quality strategy and plan, in accordance with AS9100 or higher level standard; analyze quality measures indicated in the quality plan.	Evaluate and revise a quality strategy and plan in accordance with AS9100 or higher level standard.
Developing the manufacturing and quality elements of the test and evaluation master plan (TEMP), the systems engineering plan (SEP), the integrated master schedule (IMS), the integrated master plan (IMP), and the Life Cycle Sustainment Plan (LCSP), based on program goals/objectives, identified risk, and entrance and exit criteria.	Describe the manufacturing and quality elements of the TEMP, SEP, IMS, IMP, and the LSCP, based on program goals/objectives, identified risk, and entrance and exit criteria.	Interpret and examine the implications of the manufacturing and quality elements of the TEMP, SEP, IMS, IMP, and the LSCP, based on program goals/objectives, identified risk, and entrance and exit criteria.	Evaluate the implications of the manufacturing and quality elements of the TEMP, SEP, IMS, IMP, and the LSCP, based on program goals/objectives, identified risk, and entrance and exit criteria; and revise, as needed.
Developing a manufacturing technology roadmap for the future.	Describe the considerations for the development of a manufacturing technology roadmap.	Develop a preliminary manufacturing technology roadmap and interpret and examine its implications.	Evaluate the manufacturing technology roadmap; and revise, as needed.

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Integrating the long term product technology plan with the long term manufacturing capability development plan.	Describe the importance of integrating the long term product technology plan with the long term manufacturing capability development plan.	Analyze factors affecting the integration of the long term product technology plan with the long term manufacturing capability development plan.	Formulate and implement a strategy for integrating the long term product technology plan with the long term manufacturing capability development plan.

3. Special Tooling and Test Equipment (STTE)/Government Furnished Equipment (GFE)

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Ensuring STTE conforms to requirements.	Identify characteristics for determining whether STTE conforms to requirements.	Analyze whether STTE conforms to requirements.	Evaluate whether STTE conforms to requirements.
Monitoring STTE acquisition process.	Explain the elements necessary to monitor the STTE acquisition process.	Examine the STTE acquisition process.	Evaluate and revise the STTE acquisition process.
Maintaining STTE.	Describe elements of maintaining STTE.	Develop and execute a process for maintaining STTE.	Evaluate the effectiveness of maintaining STTE.
Reviewing STTE final disposition.	Describe the characteristics of STTE final disposition plan.	Examine STTE final disposition plans.	Evaluate and revise the STTE final disposition plan.
Overseeing inventory control and distribution support of STTE/GFE.	Describe the characteristics for oversight of inventory control and distribution support of STTE/GFE.	Employ and analyze oversight of inventory control and distribution support of STTE/GFE.	Evaluate the effectiveness of oversight of inventory control and distribution support of STTE/GFE.

4. Production Line Shutdown/Restart

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Developing and maintaining shut-down plans to ensure all key production elements (i.e., technical data, equipment, automated test equipment, tooling, etc.) are captured and retained throughout the supply chain.	Recognize tasks associated with shut-down plans to ensure all key production elements (i.e., technical data, equipment, automated test equipment, tooling, etc.) are captured and retained throughout the supply chain.	Apply and analyze shut-down plans to ensure all key production elements (i.e., technical data, equipment, automated test equipment, tooling, etc.) are captured and retained throughout the supply chain.	Develop and evaluate shut-down plans to ensure all key production elements (i.e., technical data, equipment, automated test equipment, tooling, etc.) are captured and retained throughout the supply chain.
Identifying, capturing, and retaining the critical knowledge and skill sets identified throughout the supply chain.	Recognize critical knowledge and skills sets associated with shut-down plans to be identified, captured, and retained throughout the supply chain.	Categorize and analyze critical knowledge and skill sets associated with shut-down plans to be identified, captured, and retained throughout the supply chain.	Design and evaluate approaches to ensure that critical knowledge and skill sets are identified, captured, and retained throughout the supply chain.
Planning for production line (and its associated supply chain) verification, first article test, process proofing, data management, and critical item control to ensure efficient restart of production line.	Recognize tasks necessary for production line (and its associated supply chain) verification, first article test, process proofing, data management, and critical item control to ensure efficient restart of production line.	Apply and analyze processes for production line (and its associated supply chain) verification, first article test, process proofing, data management, and critical item control to ensure efficient restart of production line.	Develop and evaluate processes for production line (and its associated supply chain) verification, first article test, process proofing, data management, and critical item control to ensure efficient restart of production line.

TIER 8. Contracting Support

1. Pre-Award Support Activities

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Demonstrating awareness of the existence, purpose, and relationship between the acquisition strategy, acquisition plan, and request for proposal (RFP) to provide input into or validate the consistency of production and manufacturing requirements throughout a system's acquisition cycle.	Explain the existence, purpose, and relationship between the acquisition strategy, acquisition plan, and RFP to provide input into or validate the consistency of production and manufacturing requirements throughout a system's acquisition cycle.	Examine the existence, purpose, and relationship between the acquisition strategy, acquisition plan, and RFP to provide input into or validate the consistency of production and manufacturing requirements throughout a system's acquisition cycle.	Evaluate the existence, purpose, and relationship between the acquisition strategy, acquisition plan, and RFP to provide input into or validate the consistency of production and manufacturing requirements throughout a system's acquisition cycle; revise as needed.
Determining contractor requirements and deliverables in RFPs and requests for information (RFIs) related to carrying out PQM functions and responsibilities that are appropriate for the current phase of acquisition.	Describe the types of appropriate contractor requirements and deliverable in RFPs and RFIs related to carrying out PQM functions and responsibilities that are appropriate for the current phase of acquisition.	Examine the types of appropriate contractor requirements and deliverables in RFPs and RFIs related to carrying out PQM functions and responsibilities that are appropriate for the current acquisition phase.	Evaluate and revise the contractor requirements and deliverables in RFPs and RFIs related to carrying out PQM functions and responsibilities that are appropriate for the current acquisition phase.
Developing source selection evaluation criteria related to manufacturing/production, quality management, manufacturing risk reduction and contractor past performance.	Identify the types of source selection evaluation criteria related to manufacturing/production, quality management, manufacturing risk reduction and contractor past performance.	Examine different source selection evaluation criteria related to manufacturing/production, quality management, manufacturing risk reduction and contractor past performance.	Assess and revise different source selection evaluation criteria related to manufacturing/production, quality management, manufacturing risk reduction and contractor past performance.
Contributing to preparation of a proposal that meets the established requirements.	Discuss the elements of a proposal that meets established requirements.	Analyze whether or the degree to which a proposal meets the established requirements.	Evaluate how well a proposal meets the established requirements; revise as required.
Developing the data for learning curves and cost improvement curves.	Describe learning curves and cost improvement curves.	Develop and interpret the data for learning curves and cost improvement curves.	Evaluate and revise the data for learning curves and cost improvement curves.
Supporting pre-award surveys of technical capabilities, financial viability, and supplier certification.	Describe manufacturing-related elements for pre-award surveys of technical capabilities, financial viability, and supplier certification.	Develop and analyze pre-award surveys of technical capabilities, financial viability, and supplier certification.	Evaluate and revise pre-award surveys of technical capabilities, financial viability, and supplier certification.

2. Source Selection and Contract Negotiation

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Identifying risks associated with 1) gaps between contract proposal and requirements; 2) staying on schedule; and 3) meeting production and life-cycle cost targets.	Describe how to identify risks associated with 1) gaps between contract proposal and requirements; 2) staying on schedule; and 3) meeting production and life-cycle cost targets.	Interpret how proposals identify risks associated with 1) gaps between contract proposal and requirements; 2) staying on schedule; and 3) meeting production and life-cycle cost targets.	Assess and evaluate how proposals identify risks associated with 1) gaps between contract proposal and requirements; 2) staying on schedule; and 3) meeting production and life-cycle cost targets.
Evaluating the adequacy of risk mitigation plans and processes in proposals.	Describe the characteristics of effective risk mitigation plans and processes in proposals.	Analyze the adequacy of risk mitigation plans and processes in proposals.	Assess and evaluate the adequacy of risk mitigation plans and processes in proposals.
Identifying manufacturing-related quantitative and qualitative strengths of proposals.	Recognize elements of a proposal that indicate manufacturing-related quantitative and qualitative strengths.	Examine and interpret the manufacturing-related quantitative and qualitative strengths of proposals.	Assess and evaluate the manufacturing-related quantitative and qualitative strengths of proposals.
Supporting negotiations of contracts, contract modifications, and/or overhead rates through preparation of Technical Support to Negotiations (TSN) material by providing contracting officers with an assessment of the adequacy, reasonableness, and necessity of proposed contractor labor and material charges.	Describe the manufacturing-related elements of the negotiation of contracts, contract modifications, and/or overhead rates through preparation of TSN material; and recognize factors of these instruments that indicate the adequacy, reasonableness, and necessity of proposed contractor labor and material charges.	Propose strategies for supporting the manufacturing-related elements of the negotiation of contracts, contract modifications, and/or overhead rates through preparation of TSN material; and analyze the adequacy, reasonableness, and necessity of proposed contractor labor and material charges.	Evaluate and refine strategies supporting the manufacturing-related elements of the negotiation of contracts, contract modifications, and/or overhead rates through preparation of TSN material; and assess the adequacy, reasonableness, and necessity of proposed contractor labor and material charges.
Using source selection evaluation criteria to evaluate how well contractor proposals meet quality and manufacturing requirements.	Describe the source selection criteria being used to evaluate how well contractor proposals meet quality and manufacturing requirements.	Interpret and use the program's source selection evaluation criteria to examine how well contractor proposals meet quality and manufacturing requirements.	Interpret and use the program's source selection evaluation criteria to examine how well contractor proposals meet quality and manufacturing requirements.

3. Post-Award Support Activities

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Demonstrating awareness of the purpose, process, importance of, and roles/responsibilities associated with the post-award conference, as it relates to manufacturing.	Describe the purpose, process, importance of, and roles/responsibilities associated with the post-award conference, as it relates to manufacturing.	Examine the purpose, process, importance of, and roles/responsibilities associated with the post-award conference, as it relates to manufacturing; and propose a preliminary approach.	Evaluate the purpose, process, importance of, and roles/responsibilities associated with the post-award conference, as it relates to manufacturing; and revise preliminary approach, as needed.
Determining contractor requirements and deliverables in contracts, related to carrying out PQM functions and responsibilities that are appropriate for the current phase of acquisition.	Describe the characteristics of contractor requirements and deliverables in contracts, related to carrying out PQM functions and responsibilities that are appropriate for the current phase of acquisition.	Interpret contractor requirements and deliverables in contracts, related to carrying out PQM functions and responsibilities that are appropriate for the current phase of acquisition.	Evaluate contractor requirements and deliverables in contracts, related to carrying out PQM functions and responsibilities that are appropriate for the current phase of acquisition.
Determining implied requirements necessary to achieve contract requirements and deliverables.	Describe the types of implied requirements necessary to achieve contract requirements and deliverables.	Interpret the implied requirements necessary to achieve contract requirements and deliverables.	Evaluate the implied requirements necessary to achieve contract requirements and deliverables.
Aligning sources of funding to approved costs.	Describe the importance of aligning sources of funding to approved costs.	Interpret whether sources of funding are aligned to approved costs.	Evaluate whether or the degree to which sources of funding are aligned to approved costs.
Analyzing and resolving issues regarding prime/subcontractor relationships, contract changes, amendments, modification, and contract change notices.	Recognize issues regarding prime/subcontractor relationships, contract changes, amendments, modifications, and contract change notices.	Interpret issues regarding prime/subcontractor relationships, contract changes, amendments, modification, and contract change notices.	Evaluate the issues and corresponding resolutions regarding prime/subcontractor relationships, contract changes, amendments, modification, and contract change notices.
Supporting "progress payment" and award fee plans and determination, through an assessment of contractor delivery progress and production performance.	Describe the elements of an assessment of contractor delivery progress and production performance, as related to “progress payment” and award fee plans and determination.	Interpret elements of an assessment of contractor delivery progress and production performance to support “progress payment” and award fee plans and determination; and develop preliminary recommendations.	Evaluate the elements of an assessment of contractor delivery progress and production performance to support “progress payment” and award fee plans and determination; and revise preliminary recommendations.
Supporting manufacturing-related contract administration activities.	Describe manufacturing-related contract administration activities.	Examine manufacturing-related contract administration activities.	Evaluate and revise manufacturing-related contract administration activities.
Supporting contract close-out studies.	Describe manufacturing-related elements of contract close-out studies.	Interpret the manufacturing-related elements of contract close-out studies.	Evaluate the manufacturing-related elements of contract close-out studies.

TIER 9. Risk Management

1. Audit/Review Planning, Execution, and Documentation

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Developing audit criteria, applicable performance standards, and associated checklists to facilitate team's evaluation of performance and required supporting material and/or data for a final report.	Recognize audit criteria, applicable performance standards, and associated checklists to facilitate team's evaluation of performance and required supporting material and/or data for a final report.	Draft audit criteria, applicable performance standards, and associated checklists to facilitate team's evaluation of performance and required supporting material and/or data for a final report.	Evaluate and revise audit criteria, applicable performance standards, and associated checklists to facilitate team's evaluation of performance and required supporting material and/or data for a final report.
Identifying audit team members with appropriate expertise in the product/process to be audited to obtain proper level of coverage.	Suggest audit team members with appropriate expertise in the product/process to be audited to obtain proper level of coverage.	Select audit team members with appropriate expertise in the product/process to be audited to obtain proper level of coverage.	Evaluate and replace audit team members with appropriate expertise in the product/process to be audited to obtain proper level of coverage.
Developing schedule for audits and reviews for both internal audit team and contractor to allow sufficient time to prepare, gain customer buy-in, and achieve the intended purpose.	Draft preliminary schedule for audits and reviews for both internal audit team and contractor to allow sufficient time to prepare, gain customer buy-in, and achieve the intended purpose.	Establish schedule for audits and reviews for both internal audit team and contractor to allow sufficient time to prepare, gain customer buy-in, and achieve the intended purpose.	Evaluate and revise schedule for audits and reviews for both internal audit team and contractor to allow sufficient time to prepare, gain customer buy-in, and achieve the intended purpose.
Communicating information regarding all phases and schedules allowing sufficient time to prepare and gain customer buy-in and achieve the intended purpose.	Describe all phases and schedules and discuss how they allow for sufficient time to prepare and gain customer buy-in and achieve the intended purpose.	Analyze all phases and schedules and explain how they allow for sufficient time to prepare and gain customer buy-in and achieve the intended purpose.	Evaluate all phases and schedules to assure they allow for sufficient time to prepare and gain customer buy-in and achieve the intended purpose; and modify, as needed.
Conducting quality audits/reviews and support all reviews and audits.	Participate in quality audits/reviews and support all reviews and audits.	Lead low complexity quality audits/reviews and support all reviews and audits.	Lead high complexity quality audits/reviews and support all reviews and audits.
Documenting findings from audits/reviews to clearly identify audit scope, criteria, and findings.	Record findings from audits/reviews to clearly identify audit scope, criteria, and findings.	Organize findings from audits/reviews to clearly identify audit scope, criteria, and findings.	Assess findings from audits/reviews to clearly identify audit scope, criteria, and findings.

2. Proactive Risk Identification

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Preparing manufacturing elements of in-process reviews, non-conformance material assessment, and compliance reviews, and design reviews.	Suggest manufacturing elements of in-process reviews, non-conformance material assessment, compliance reviews, and design reviews.	Develop manufacturing elements of in-process reviews, non-conformance material assessment, compliance reviews, and design reviews.	Evaluate and revise manufacturing elements of in-process reviews, non-conformance material assessment, compliance reviews, and design reviews.
Planning and conducting production readiness reviews (PRRs) and assessments of manufacturing readiness.	Recognize key elements of a plan to conduct PRRs and assessments of manufacturing readiness.	Develop a plan to conduct and lead low risk elements of PRRs and assessments of manufacturing readiness.	Evaluate and revise plans to conduct and lead complex elements of PRRs and assessments of manufacturing readiness.
Identifying products with single, sole, or foreign sources or potential obsolescence issues to highlight potential risks to DOD supply.	Locate products with single, sole, or foreign sources or potential obsolescence issues to highlight potential risks to DOD supply.	Analyze situations involving products with single, sole, or foreign sources or potential obsolescence issues to highlight potential risks to DOD supply.	Evaluate situations involving products with single, sole, or foreign sources or potential obsolescence issues to assess the severity of potential risks to DOD supply.
Identifying and evaluating critical suppliers and schedules to ensure sub-contracted requirements support production schedules.	Describe potential situations that involve critical suppliers and schedules to ensure sub-contracted requirements support production schedules.	Determine and analyze critical suppliers and schedules to ensure sub-contracted requirements support production schedules.	Assess and evaluate critical suppliers and schedules to ensure sub-contracted requirements support production schedules.
Identifying and evaluating manufacturing maturity of critical suppliers and sub-contractors working with the primary DOD contractor to determine risks to production.	Describe manufacturing maturity of critical suppliers and sub-contractors working with the primary DOD contractor to determine risks to production.	Determine and analyze manufacturing maturity of critical suppliers and sub-contractors working with the primary DOD contractor to determine risks to production.	Assess and evaluate manufacturing maturity of critical suppliers and sub-contractors working with the primary DOD contractor to determine risks to production.
Assessing design maturity.	Discuss elements of design maturity.	Analyze and determine design maturity.	Evaluate and revise design maturity.
Assessing a model based design for its completeness, stability, maturity, and ability to meet requirements.	Recognize elements of a model based design with respect to completeness, stability, maturity, and ability to meet requirements.	Analyze and develop a model based design to account for completeness, stability, maturity, and ability to meet requirements.	Evaluate and revise a model based design to account for completeness, stability, maturity, and ability to meet requirements.
Assessing product and process technology readiness.	Discuss elements of product and process technology readiness.	Analyze and determine product and process technology readiness.	Evaluate and revise product and process technology readiness.
Assessing performance against IMP and IMS.	Describe the consistency of performance as compared to IMP and IMS.	Analyze the consistency of performance as compared to IMP and IMS.	Evaluate the consistency of performance as compared to IMP and IMS.
Identifying metrics and management information requirements and evaluating them against standards.	Discuss metrics and management information requirements and how they can be evaluated against standards.	Determine metrics and management information requirements and analyze how they can be evaluated against standards.	Evaluate and revise metrics and management information requirements to evaluate them against standards.
Identifying best practices and conduct benchmarking.	Recognize best practices and how to conduct benchmarking.	Determine best practices and analyze benchmarking activities.	Evaluate and revise best practices and establish benchmarks.
Assessing compliance to certification criteria (e.g., ensuring there are no unqualified parts).	Discuss elements of compliance to certification criteria (e.g., ensuring there are no unqualified parts).	Analyze and determine compliance to certification criteria (e.g., ensuring there are no unqualified parts).	Evaluate and revise compliance to certification criteria (e.g., ensuring there are no unqualified parts).

3. Realized Risk Management

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Supporting failure review boards.	Describe the failure review board process.	Participate in the failure review board process.	Advise the failure review board process.
Reacting immediately to contain the effects of discovered defects.	Describe the need for immediately containing the effects of discovered defects.	Apply measures to immediately contain the effects of discovered defects.	Evaluate alternatives for immediately containing the effects of discovered defects.
Supporting failure investigation.	Describe the failure investigation process.	Participate in the failure investigation process.	Advise the failure investigation process.
Coordinating with customer and complying with regulations.	Describe the necessary actions to comply with appropriate regulations	Coordinate with customer and act to comply with regulations.	Coordinate with customer and evaluate actions to comply with regulations.
Supporting the failure reporting and corrective action system (FRACAS).	Describe FRACAS.	Utilize FRACAS.	Evaluate the adequacy of FRACAS entries or content.

4. Analysis, Corrective Action, Closure, Sharing of Lessons Learned

Competency Element	Entry-Level	Mid-Level	Advanced-Level
Performing root cause analysis.	Describe the characteristics of a root cause analysis.	Conduct a root cause analysis.	Evaluate the results of a root cause analysis and suggest alternative approaches, as needed.
Performing risk assessments to determine the severity of impact and likelihood of occurrence.	Explain risk assessments to determine the severity of impact and likelihood of occurrence.	Conduct risk assessments to determine the severity of impact and likelihood of occurrence.	Evaluate the results of risk assessments to determine the severity of impact and likelihood of occurrence.
Applying problem solving tools and performing required calculations for various risk scenarios.	Describe the use of problem solving tools to perform required calculations for various risk scenarios.	Apply problem solving tools to perform required calculations for various risk scenarios.	Evaluate how problem solving tools are used to perform required calculations for various risk scenarios; and revise, as necessary.
Applying decision analysis in the selection of risk mitigation options.	Recognize how decision analysis may be used in the selection of risk mitigation options.	Perform decision analysis to analyze and select risk mitigation options.	Evaluate the results of decision analysis in the selection of risk mitigation options; revise options, as appropriate.
Using risk management tools to predict, track, rate, and mitigate risk events, as well as identify the critical path to determine probabilities of program completion dates and costs.	Describe the use of risk management tools to predict, track, rate, and mitigate risk events, as well as identify the critical path to determine probabilities of program completion dates and costs.	Apply risk management tools to predict, track, rate, and mitigate risk events, as well as identify the critical path to determine probabilities of program completion dates and costs.	Evaluate the results of risk management tools to predict, track, rate, and mitigate risk events, as well as identify the critical path to determine probabilities of program completion dates and costs; and revise the analysis, as appropriate.
Prioritizing risk mitigation efforts.	Describe approaches to prioritizing risk mitigation efforts.	Prioritize risk mitigation efforts.	Evaluate and revise the prioritization of risk mitigation efforts.
Developing and communicating the corrective action plan to manage risk.	Describe and communicate the corrective action plan to manage risk.	Develop and apply the corrective action plan to manage risk.	Evaluate and revise the corrective action plan to manage risk.
Managing supplier changes to mitigate risks, when necessary.	Describe how supplier changes can mitigate risks.	Determine whether supplier changes to mitigate risks are necessary.	Evaluate options for making supplier changes to mitigate risks.
Correcting the root cause of identified problems.	Describe procedures for correcting the root cause of identified problems.	Apply corrective action to the root cause of identified problems.	Evaluate the effectiveness of corrective action for the root cause of identified problems.
Preventing the root cause of identified problems from creating risk in the future.	Describe the considerations for preventing the root cause of identified problems from creating risk in the future.	Determine how to prevent the root cause of identified problems from creating risk in the future; and apply preventative measures.	Evaluate the effectiveness of identifying and implementing preventative measures to address root causes of identified problems from creating risk in the future.
Drawing conclusions from audit/review findings to determine whether the audited organization satisfactorily meets defined criteria and to identify areas needing improvement, as well as areas of excellent performance.	List conclusions from audit/review findings to determine whether the audited organization satisfactorily meets defined criteria and identify areas needing improvement, as well as areas of excellent performance.	Develop preliminary conclusions from audit/review findings to determine whether the audited organization satisfactorily meets defined criteria and identify areas needing improvement, as well as areas of excellent performance.	Evaluate conclusions from audit/review findings to determine whether the audited organization satisfactorily meets defined criteria and identify areas needing improvement, as well as areas of excellent performance.
Communicating lessons learned.	Explain lessons learned.	Develop lessons learned.	Evaluate the appropriateness of lessons learned.

Appendix B
Illustrations

Figures

Appendix C
References

Aerospace Industry Competency Model. Minnesota: Employment and Training Administration, U. S. DOL, 2012. http://www.careeronestop.org/competencymodel/pyramid.aspx?AEO=Y.

Air Force Aeronautical Systems Command. *Manufacturing and Quality Assurance Acquisition Process Guide*. Wright-Patterson Air Force Base, OH: U.S. Air Force, September 1, 2011.

Army Aviation and Missile Research Development and Engineering Center (AMRDEC). *AMRDEC Quality Engineering Division Knowledge, Skills, and Abilities Survey.* Redstone Arsenal, AL: U.S. Army, December 13, 2006. Draft.

———. *KSA Groupings*. Redstone Arsenal, AL: U.S. Army, March 26, 2012.

———. *Results Summary Spreadsheet*. Redstone Arsenal, AL: U.S. Army, n.d.

———. *Survey KSA Spreadsheet*. Version 4. Redstone Arsenal, AL: U.S. Army, n.d.

Cohen, William J. *Secretary of Defense Report to Congress: Actions to Accelerate the Movement to the New Workforce Vision*. Washington, DC: Department of Defense, April 1, 1998.

Eggers, William D. and John Hagel. *Brawn from Brains—Talent, Policy and the Future of American Competitiveness.* Westlake TX: Deloitte University Press, 2012.

Employment and Training Administration. *Advanced Manufacturing Competency Model.* Minnesota: U. S. Department of Labor (DOL), April 2010. http://www.careeronestop.org/competencymodel/pyramid.aspx?hg=Y.

———. "Develop a Competency Model." Competency Model Clearinghouse. *CareerOneStop* website. Minnesota: U. S. DOL, 2012. Accessed April 19, 2012. http://www.careeronestop.org/competencymodel/cmuserguide.aspx.

Fryer-Briggs, Zachary, Pierre Tran, and Vago Muradian. "Firms Struggle to Keep Talent in Downturn." *Defense News*, July 15, 2012.

Future Acquisition and Technology Workforce Final Report. By the Section 912(c) Working Group in support of the initiatives described in the Office of the Secretary of Defense's April 1998 Report to Congress. Washington, DC: OSD, April 2000.

Mandelbaum, Jay, Rachel D. Dubin, Margaret C. Hebner, and Lucas A. LaViolet. *Effects of Recent Manufacturing Policy Changes on the Acquisition Workforce.* IDA Paper P-4584. Alexandria, VA: Institute for Defense Analyses, May 2010.

OSD Manufacturing Technology Program in collaboration with the Joint Service/Industry MRL Working Group. *Manufacturing Readiness Level (MRL) Deskbook*, v2.2. Washington, DC: U.S. Department of Defense, July 2012. http://www.dodmrl.com/MRL_Deskbook_V2_2.pdf.

President's Council of Advisors on Science and Technology. *Report to the President, Capturing a Domestic Competitive Advantage in Advanced Manufacturing; Report of the Advanced Manufacturing Partnership Steering Committee, Annex 3, Education and Workforce Development Workstream Report.* Washington, DC: Executive Office of the President, July 2012.

Quality Engineering Division, Engineering Directorate. *QE Program Activity Assessment Results.* Redstone Arsenal, AL: U.S. Army Aviation and Missile Research, Development and Engineering Center, April 21, 2010.

Shipp, Stephanie S., Nayanee Gupta, Bhavya Lal, Justin A. Scott, Christopher L. Weber, Michael S. Finnin, Meredith Blake, Sherrica Newsome, and Samuel Thomas. *Emerging Global Trends in Advanced Manufacturing*. IDA Paper P-4603. Alexandria, VA: Institute for Defense Analyses, March 2012.

Society of Manufacturing Engineers. *Certified Manufacturing Technologist and Certified Manufacturing Engineer Body of Knowledge*. Dearborn, MI: Society of Manufacturing Engineers, August 2010. Supplemented by unpublished modifications, November 4, 2011.

Under Secretary of Defense (Acquisition, Technology and Logistics) (USD(AT&L)). "Subject: Better Buying Power Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending." Memorandum. Washington, DC: Department of Defense, September 14, 2010.

———. "Subject: Better Buying Power 2.0: Continuing the Pursuit for Greater Efficiency and Productivity in Defense Spending." Memorandum. Washington, DC: Department of Defense, November 13, 2012.

U.S. Government Accountability Office (GAO) and Michael Sullivan. *Best Practices: DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed*. GAO-10-439. Washington, DC: GAO, April 22, 2010.

U.S. Government Accountability Office and Cristina T. Chaplain. *Space and Missile Defense Acquisitions: Periodic Assessment Needed to Correct Parts Quality Problems in Major Programs*. GAO-11-404. Washington, DC: GAO, June 24, 2011.

Whitt, Mike. *Gap Status.* Redstone Arsenal, AL: U.S. Army Aviation and Missile Research, Development and Engineering, July 2008.

Appendix D
Abbreviations

A&D	Aerospace and Defense
ADMCM	Aerospace and Defense Manufacturing Competency Model
AFIT	Air Force Institute of Technology
AIA	Aerospace Industry Association
AICM	Aerospace Industry Competency Model
AMP	Advanced Manufacturing Partnership
AMRDEC	U.S. Army Aviation and Missile Research Development and Engineering Center
AS	Aerospace Standard
AT&L	Acquisition, Technology and Logistics
BoK	Body of Knowledge
BCA	Benefit Cost Analysis
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAM	Computer-Aided Manufacturing
CDIO	Conceive-Design-Innovate-Operate
DAU	Defense Acquisition University
DCMA	Defense Contract Management Agency
DMSMS	Diminishing Manufacturing Sources and Material Shortage
DOD	U.S. Department of Defense
DOL	U.S. Department of Labor
FIPT	Functional Integrated Product Team
FRACAS	Failure Reporting and Corrective Action System
GAO	U.S. Government Accountability Office
GD&T	Geometric Dimensioning and Tolerancing
GFE	Government Furnished Equipment
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
ISO	International Organization for Standardization
ITAR	International Traffic in Arms Regulations

KSA	Knowledge, Skills, and Abilities
LCSP	Life-Cycle Sustainment Plan
M&S	Modeling and Simulation
MDA	Missile Defense Agency
MRL	Manufacturing Readiness Level
NDIA	National Defense Industrial Association
OSD	Office of the Secretary of Defense
PQM	Production, Quality, and Manufacturing
PRR	Production Readiness Review
RFI	Request for Information
RFP	Request for Proposal
SEP	Systems Engineering Plan
SME	Society of Manufacturing Engineers
SOW	Statement of Work
STEM	Science, Technology, Engineering and Mathematics
STTE	Special Tooling and Test Equipment
TEMP	Test and Evaluation Master Plan
TSN	Technical Support to Negotiations
V&V	Verification and Validation

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14. ABSTRACT

This study identified common manufacturing core competencies for the aerospace and defense (A&D) sector. The resulting aerospace and defense manufacturing competency model (ADMCM) describes the manufacturing community's interface with science and technology, research, design, development, production, and sustainment in a future state consistent with the Manufacturing Readiness Level (MRL) framework. The model reinforces an environment where producibility and manufacturability, design, risk management, and quality systems are fully integrated. The ADMCM is intended to be broadly available to education providers and can be used to enable certification programs, therefore its competency elements were designed to be objectively measured and assessed.

15. SUBJECT TERMS

Manufacturing competency model, manufacturing readiness levels, MRL, aerospace and defense competencies, PQM competency model

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