**"What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency"**

| | |
|---|---|
| *Moderator:* | *Don Gelosh, SAIC* |
| *Panelists:* | *Arthur Pyster, Stevens Institute of Technology* |
| | *John Snoderly, Defense Acquisition University* |
| | *Samantha Brown, BAE Systems* |
| | *Mark Kupeski, IBM* |
| | *U Dinesh Kumar, Indian Institute of Management Bangalore* |
| | *Stephen Cook, Defence and Systems Institute, University of South Australia* |

**Biographies:**

*Moderator:*

**Dr. Don Gelosh** is the Assistant Deputy Director for Human Capital Strategy and Planning in the OSD Directorate of Systems and Software Engineering. Dr. Gelosh provides expertise in the areas of human capital development, education, training, experience, competency and knowledge management, and outreach. He has over 33 years of combined experience from the US Air Force, government, industry, and academia. He has served as Director of the Regional International Outreach program and Dean of Learning and Technology at the National Defense University, Deputy Head of the Electrical and Computer Engineering Department at the Air Force Institute of Technology, and Instructor at the US Air Force Academy. Dr. Gelosh also worked as a systems engineer on the Space Shuttle as a member of NASA's Vehicle Integration and Test Team where he was responsible for communications and payload integration and ensuring the Shuttle was ready for launch. Dr. Gelosh received a PhD in Electrical Engineering from the University of Pittsburgh in 1994, a MS in Computer System Design from the University of Houston at Clear Lake in 1989, and a BS in Electrical Engineering from the Ohio State University in 1981. Dr. Gelosh is also an INCOSE Certified Systems Engineering Professional with the DoD Acquisition extension.
Nationality: USA

*Panelists:*

**Dr. Arthur Pyster** is a Distinguished Research Professor in the School of Systems and Enterprises at Stevens Institute of Technology and the Deputy Executive Director of the Systems Engineering Research Center, which is the Department of Defense Systems Engineering Research Center which is operated by Stevens. Before joining Stevens in March 2007, Dr. Pyster held a number of senior executive and technical positions, including Senior Vice President and Director of Systems Engineering and Integration for SAIC and Deputy Chief Information Officer for the Federal Aviation Administration. Among his accomplishments, Dr. Pyster directed the creation of three Capability Maturity Models, oversaw more than $10 billion in investment, delivered commercial telecommunications systems with extremely low defects, and architected and operated the information security program for the Federal Aviation Administration. He is the Chairman of the INCOSE Corporate Advisory Board and a member of the INCOSE Board of Directors.
Nationality: USA

**Dr. John Snoderly** is currently the Program Director of Systems Engineering at the Defense Acquisition University. He is responsible for the development of SE courses as well as providing instruction on management of the Systems Engineering aspects of the Department of Defense systems acquisition process. He has been a faculty member at DSMC/ DAU since December of 1979 and is the recognized DAU authority at the University on Systems Engineering. He is the

person responsible for education of the DoD Acquisition Workforce in SE and has developed both on-line courses and classroom instruction for the University. From 2001 to 2003, as an Associate Professor at George Mason University School of Management, Dr. Snoderly conducted an executive postgraduate level seminar for Chief Information Officers and Program Management course for the GMU Masters of Technology Management program's 2003 fall semester. Dr. Snoderly was also the first President of the Washington Chapter of the International Council on Systems Engineering INCOSE in 1991 and served as the President of INCOSE from 2002-2004.
Nationality: USA

**Samantha Brown** is the current President-Elect of INCOSE, having served as INCOSE Technical Director from 2004-2007. She will become INCOSE President in January 2010. Samantha has over 20 years experience in the UK defence industry, working in a wide range of roles before moving into systems engineering. In 1999 she was appointed Deputy Chairman of the BAE Systems 'Systems Engineering Council', a role in which she was responsible for the coordination of corporate systems engineering capability development. She received a SPIRE award for her service to systems engineering education & training within the company in 2004. Samantha holds a BSc in Mechanical Engineering from the University of Bath, UK, MScs in Gun Systems Design from the Royal Military College of Science, Shrivenham, UK and in Engineering Management from the University of Bristol, UK, is a Chartered Engineer and Fellow of the Institution of Mechanical Engineers. She is based at the Systems Engineering Innovation Centre (SEIC) in Loughborough, UK where she is currently studying for an Engineering Doctorate (EngD) in Systems Engineering. Her research, which is sponsored by BAE Systems, focuses on the application of systems engineering techniques to the social aspects of complex multi-organisation systems of systems.
Nationality: British

**Mark Kupeski** is the Director, Complex Systems Integration, IBM Global Business Services. Mark has more than 25 years of industry experience in the areas of solution design and proposals for complex systems, project management and delivery of complex systems development projects and systems engineering of complex systems including both hardware and software components. His career has included work in a variety of technical, Project Management, Systems Engineering and management positions in both commercial and US Government projects. He has participated in and managed the design, test, deployment, and supportability of large, complex systems for both commercial and military applications. He has led and contributed to Systems Engineering process development in IBM from May 2001 to present. In addition to his broad experience in Systems Engineering and solution design he is currently an IBM Certified Executive Project Manager.
Nationality: USA

**Dr U Dinesh Kumar** is a Professor in Quantitative Methods and Information Systems at Indian Institute of Management Bangalore. U Dinesh Kumar holds a Ph.D. in Mathematics from IIT Bombay and M.Sc. in Applied Sciences (Operations Research) from P.S.G. College of Technology, Coimbatore. Dr Dinesh Kumar has over 11 years of teaching and research experience. Prior to joining IIM Bangalore, Dr Dinesh Kumar has worked at several reputed Institutes across the world including Stevens Institute of Technology, USA; University of Exeter, UK; University of Toronto, Canada; Federal Institute of Technology, Zurich, Switzerland; Queensland University of Technology, Australia; Australian National University, Australia and the Indian Institute of Management Calcutta.

Dr Dinesh Kumar's research interests include Pricing and Revenue Management, Defence logistics, Reliability, Maintainability, Logistics support, Spare parts provisioning, Six Sigma, supply chain architecture, decision making and systems thinking. Dr Dinesh Kumar has written two books and over 50 articles in refereed International journals. Dr Dinesh Kumar is the Associate

Editor of the Journal OPSEARCH, the Journal of Operational Research Society of India. He is also the editorial member of the Journal Risk and Reliability published by the Institution of Mechanical Engineers (IMechE), UK and ad-hoc referee for several International journals in Operations Research and Systems Engineering.

Dr U D Kumar serves as an academic council member of Anna University Trichy and member of board of studies of MBA programme of Anna University, Trichy. Dr Dinesh Kumar was awarded the best young teacher award by the Association of Indian Management Schools for the year 2003. The complete CV of Professor U D Kumar can be downloaded from the following link.

http://www.iimb.ernet.in/iimb/html/m-frames.jsp?ilink=111&pname=faculty.jsp&areaid=9

Nationality: Indian

**Prof Stephen Cook** is the Director of the Defence and Systems Institute at the University of South Australia. He commenced his career in the telecommunications and aerospace industries in which he designed numerous innovative products that sold in volume. In the latter part of this period he was appointed project engineer and provided technical leadership for aerospace integration projects. After ten years he left industry to join the Defence Science and Technology Organisation (DSTO) rising to Research Leader Military Information Networks responsible for all military communications and networking research and all related studies for the Australian Department of Defence. In 1997 he transferred to the university as the DSTO Professor of Systems Engineering and has led various defence research concentrations since. Prof Cook is a Past President of the Systems Engineering Society of Australia and his research interests include systems modelling, defence capability engineering, and identifying the theoretical basis for systems engineering.
Nationality: Australian

# Position Paper for Panel 304

# What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency


| | |
|---|---|
| Panelist (and Moderator): | Don Gelosh |
| Topic: | Systems Engineering Competency Model for US DoD |


In support of the June 2006 DoD Acquisition Technology and Logistics (AT&L) Human Capital Strategic Plan, the Defense Acquisition University, in conjunction with the Center for Naval Analysis, has been developing competency models for several career fields within the AT&L community. These competency models are being designed to define the observable, measurable patterns of knowledge, skills, abilities, behaviors and other characteristics that the acquisition workforce needs to perform successfully on the job for a particular career field.

**My Position.**

My panel presentation will focus on the competency model being developed for the DoD Systems Planning, Research, Development, and Engineering career paths of Systems Engineering and Program Systems Engineer. My position is that if you consider this competency model as the set of baseline performance requirements for high-performing Systems Engineers, the model can then be further developed and refined through well known systems engineering methods and best practices. Properly analyzed and developed, the competencies in the model can then be allocated to drive education, training, and experience opportunities. When these opportunities are implemented and properly integrated with our systems engineering candidates, these candidates' resultant knowledge, skills, abilities, and behaviors can be verified and validated and the candidates can transition into the true systems engineering workforce. The desired end-state solution is a high-performing systems engineering workforce that can lead and manage the complex technical aspects of our acquisition programs and contribute to their overall success, thereby accomplishing the AT&L mission: providing critical capabilities to the warfighter.

**Competencies as Performance Requirements.**

The systems engineering competencies can be viewed and treated as performance requirements for success. This section describes how the competency model was developed and validated through a four phase process. This process very much resembles a requirements development process.

During the first phase of the competency model development, a panel of executive-level experts in systems engineering (the stakeholders) developed the initial competency model framework. The initial framework included systems engineering competencies that were derived from policy and guidance, current training, best practices, and professional leadership competency models. The competencies were grouped into areas of competence that included Analytical, Technical Management, General, and Professional. The Analytical area included competencies for systems engineering tools, techniques, design considerations, and technical processes. The Technical Management area included competencies for the technical management processes. The General area included competencies for the total systems view. The Professional area included a wide range of professional competencies such as communications, decision making, interpersonal skills, and team building. Each of these competencies was further decomposed into elements that described the required behaviors for the competency.

During the second phase, a group of hand-picked subject matter experts validated the framework to create the final model. These subject matter experts were identified by their respective organizations as their top performers and they covered a wide range of functional areas in systems engineering. The subject matter experts completed a four-hour on-line assessment of the competency model framework and provided several work situations where they used systems engineering techniques to solve problems.

During the third phase, results from the subject matter expert validation will be analyzed and the competency model will be further refined to include input from the functional leaders in systems engineering. These functional leaders include the senior executives in AT&L with oversight responsibilities for systems engineering across the DoD. This is done to prepare and finalize the competency for the final phase.

During the fourth and final phase, the competency model will be used to assess the entire systems engineering workforce in the DoD Acquisition Corps. The results of this assessment will then be used to identify competencies required for superior performance, evaluate proficiency gaps for validated competencies, and plan for continual updates and use of the competency model. These assessment results and the competency model will also be used to drive revisions to the training curriculum at the Defense Acquisition University and to drive other changes to the DoD certification standards which cover education, training, and experience requirements. This will require a full analysis of the competency model to properly allocate the individual competencies and their elements to education, training, and experience opportunities.

**Allocation of Competency Elements to Education, Training, and Experience Opportunities.**

In the final competency model, each element will have an associated set of knowledge, skills, and abilities that will enable success for that element. Further analyses of these knowledge items will show if they are best acquired through education, training, or experience or some combination thereof.

For example, one of the most important competencies in the Technical Management area is Risk Management. One of the elements for Risk Management states as its desired behavior: "Develop a Risk Management Plan to cover system and software risk elements in order to assess and manage the risks throughout the system life cycle."

There are several knowledge items associated with this element such as:

- Knowledge of risk management tools and techniques
- Knowledge of government constraints
- Knowledge of failures that occurred on past similar efforts
- Knowledge of technical challenge areas in each applicable discipline for the system
- Knowledge of developers' capabilities

Knowledge of risk management tools and techniques and government constraints could be acquired through a combination of education and training. On the other hand, knowledge of past failures could be acquired through training in the form of case studies, but would probably more likely be acquired through experience. Knowledge of technical challenge areas could be acquired through training, but experience may be a better teacher in this area. The same holds true for knowledge of the developers' capabilities – experience with the developers would be key in knowing what they are capable of achieving on an acquisition program.

The point here is that the knowledge items that will enable the desired behavior for this risk management element can be acquired through a combination of education, training, and experience. Careful analysis combined with past experience in curriculum development and human capital planning will determine which of the three will provide the best results.

Once we have an allocation of the competencies and their associated elements to education, training, and experience opportunities, we can turn our attention to implementing these opportunities and integrating them into the systems engineer candidates' individual development programs.

**Implementation and Integration.**

Implementing these education, training, and experience opportunities requires associations and partnerships among the government, academic, and industry communities in systems engineering. Formal educational programs in systems engineering at both the undergraduate and graduate levels are growing. Whenever and wherever possible, we should establish and continue a dialogue or partnership with these academic institutions so their programs can cover the appropriate knowledge items. Formal corporate training programs exist in both the DoD (e.g., Defense Acquisition University) and industry for systems engineering. Again, we should strive to establish and maintain a dialogue and partnership with industry and their corporate universities as well. In the area of experience opportunities, we can establish and enhance existing internship programs, rotational assignments, and mentoring opportunities to name a few. There is a school of thought that one can only become a true systems engineer through the hard knocks and resultant scar tissue that experience provides.

In the area of integration, it is very important that the systems engineer candidate is properly integrated with the required competencies through the appropriate mix of education, training, and experience. It is also important that these three paths to acquiring the competencies provide a good alignment and consistency. It would cause much confusion for our candidate if they were to learn different and inconsistent things about any of the competencies. Unfortunately, this happens a lot and contributes to failures in some programs. For example, a systems engineer candidate may learn some foundational knowledge about risk management at their graduate school, only to learn something very different at their corporate training university, and then be asked to manage risk in a completely different way at their job. With the right partnering and dialogue among the government, academic, and industry systems engineering communities these situations can be minimized and mitigated if needed.

**Verification, Validation, and Transition.**

The final steps in our competency development process are verification, validation, and transition. The verification and validation processes can be satisfied through obtaining degrees, certificates, and professional certifications, such as the INCOSE – Certified Systems Engineering Professional with Acquisition extension (CSEP-Acq). For example, the acquisition portion of the INCOSE CSEP-Acq certification exam is based on the DoD's Defense Acquisition Guidebook (DAG), Chapter 4, Systems Engineering. Of course, the DoD competency model is also based in part on the DAG. Therefore, when one obtains this particular certification, you can be assured that they have a firm knowledge of Chapter 4 in the DAG.

The important aspect of transition is ensuring that the newly credentialed systems engineer is properly utilized at the appropriate level and offered the opportunity to continuously learn and excel. The competency model should provide performance requirements for all levels such as entry, journeyman, and expert. The subsequent personal development through education, training, and experience should reflect the appropriate level of desired achievement as well. Finally, the systems engineers should be encouraged to obtain higher and higher levels of competencies on a continuous basis.

**Summary.**

This paper describes my position on how a competency model can be used as a set of performance requirements that can be processed using systems engineering methods to drive education, training, and experience opportunities for those wishing to become true systems engineers. The competency model should provide performance requirements for all levels such as entry, journeyman, and expert. It's worth repeating that the desired end-state solution is a high-performing systems engineering workforce that can lead and manage the complex technical aspects of our acquisition programs and contribute to their overall success, thereby accomplishing the AT&L mission: providing critical capabilities to the warfighter.

**Position Paper for Panel 304**

# What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency

Systems Engineering Competencies for Enterprise Systems

Arthur Pyster
Stevens Institute of Technology
art.pyster@stevens.edu

The competencies on which today's systems engineers commonly rely often fall short when considering enterprise systems. Enterprise systems are massively complex and interconnected, owned by diverse stakeholders, deeply dependent on new software technologies and commodity hardware, emerge and evolve over time, and defy traditional methods of analysis and construction. One of the best examples of such a system is the U.S. national airspace system (NAS). Several key characteristics of the NAS:

1. The NAS is a net-centric system of systems containing thousands of individual system elements exchanging massive amounts of information. Because of how the NAS is designed, elements routinely fail or are impaired by weather without any significant degradation in flight safety.
2. The U.S. Federal Aviation Administration (FAA) regulates and operates elements of the NAS through a multi-billion dollar collection of equipment and software, a workforce of 50,000 employees, and many thousands more contractors.
3. The FAA owns and operates thousands of pieces of equipment dispersed across the U.S. enabling navigation, surveillance, communication, and management of air traffic.
4. The FAA does not own or operate the aircraft, airlines, airports, weather reporting system, and many other system elements that are integral to the NAS. The FAA can influence the arrival, departure, and behavior of those other elements, but does not directly control them.
5. The functionality of virtually all NAS equipment developed in the last 15 years depends very heavily on complex custom software, often combined with commercial off the shelf components.
6. The NAS is continually being upgraded, reflecting new technologies, such as satellite-based surveillance rather than radar-based surveillance. Those upgrades must be done conscious of the massive amount of legacy equipment in place and the need to maintain full operational continuity and safety while upgrades and changes occur.
7. The complexity of the NAS is so great that it is not possible to build high fidelity models that fully explain its dynamic behavior as new equipment is introduced and operational procedures are changed.

The FAA has an ambitious plan to add billions of dollars in new equipment over the next 15 years creating what they call the next generation air traffic control system or NextGen. NextGen will offer much greater situational awareness for pilots, better automation on the ground and in aircraft, and enable a significant reduction in the amount of space and time that separate aircraft in flight. With these improvements, pilots and airlines will be given commensurately greater control over the speed, altitude, and direction of their aircraft. Together, all these improvements will enable air traffic to safely double over today's levels.

Ambitious plans such as those of the FAA are not unique. Massive investment in health care, renewable energy, financial reregulation, homeland security, food safety, and many other dimensions of society are planned or underway in the United States and elsewhere throughout the world. Each one of these enterprise efforts is unique, but all share most of the characteristics of the NAS and NextGen cited above.

Given the need to develop and evolve complex enterprise systems, the challenges facing systems engineers are unprecedented. Beyond traditional competencies, systems engineers must be strong in:

a. *Complexity* – the behavior of enterprise systems is not subject to tractable mathematical treatment, is non-linear and changes as the system evolves.

b. *Systems thinking* – for enterprise systems, the interaction among the various system components, unanticipated effects from changes, porous system boundaries, and a myriad of other characteristics all demand systems thinking, not just traditional analytic approaches.

c. *Systems engineering at very-large scale or ultra-large scale* – systems engineering techniques (concept of operations, architecting, requirements engineering, integration, verification, and validation), used in developing "normal" systems, don't scale for very-large and ultra-large systems. For example, a complete set of requirements cannot be written and the usage scenarios are far too many and complex for complete verification.

d. *Software engineering* – with the majority of functionality and behavior of virtually all enterprise systems delivered through software, system engineers need a deep understanding of how to build scalable trustworthy software.

e. *Modeling and simulation* – sophisticated models and simulations help developers understand the quality (non-functional) properties (safety, security, robustness, and other "ilities") of their enterprise solution well enough to give confidence it will meet the evolving needs of the stakeholders.

f. *Development and acquisition governance* – deciding or even describing decision rights, policies, infrastructure, controls, and measures for development is critical when no single entity is in charge and stakeholders have competing interests.

g. *Systems evolution* – systems must be designed for continual evolution and must accommodate unplanned evolution after fielding.

h. *Agile development and systems* – system development approaches must leverage new opportunities and defend well against threats.

Industry and government must ensure their workforce has mastered these 8 competencies in order to address enterprise systems.

## Position Paper for Panel 304

## What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency

**Panelist** – Dr. John R. Snoderly

**Panel:** What Defines a Systems Engineer? Comparing and Contrasting Global Per-

spectives on Systems Engineering Competency.

March 10, 2009

**Topic-**US Government and US Industry differences in approach to using SE in the Defense Industry.

There is a completely different approach to the use of systems engineers in the government versus Industry. In the former case the government is largely looking to develop a top level functional specification spelling out what the capabilities of a particular product are through the formulation of top level requirements. The Contractor on the other hand has an interest in developing a product that meets the government's expectations as well as being able to produce it while making a profit on the sale of it to the Government. I will be discussing the Technical Management areas as defined in the US Department of Defenses Acquisition Guide. The competencies involved in technical management are Decision Analysis, Technical Planning,Technical Assessment, Requirements Management, Risk Management, Configuration Management , Interface Management, Technical Data Packages. In addition to these, the competencies listed in the enclosed Table are Specifications, Earned Value Management, Technical Reviews, Software Engineering, and Systems Engineering by Phases. These are shown in the middle column of the attached table. The table was developed by a panel of experts in the Systems Planning Research Development and Engineering (SPRDE) portion of the US Governments Acquisition career field.

The government engineer is heavily involved in technical management of the program and primarily monitors what the contractor is doing during the development through the evaluation of metrics. The government systems engineer must be competent in all of the technical management areas, previously mentioned, if he is going to be a successful technical manager. The first competency in the enclosed table under the technical management area deals with how does the contractor use the decision analysis process when a formal decision is needed or when the effectiveness of an alternative needs to be determined. It is important that the trade-off analysis conducted, was based upon a sound technical process.

The next competency in the table looks at the technical planning and how well the contractor is following the technical planning efforts as shown in the contractors Systems Engineering Management Plan (SEMP). Also,does those plans match up with the Government prepared Systems Engineering Plan (SEP). Here also is where the systems engineer must work closely with the Program Manager to make certain that everyone is clear about the technical approach to be taken and to develop an integrated management plan and schedule.

Technical Assessment activities measure technical progress and the effectiveness of plans and requirements. Government engineers must know how the contractor is performing technical assessment measures by assessing the contractor's technical progress toward satisfying stakeholder technical requirements.

Activities within Technical Assessment include the activities associated with technical performance measurement and the conduct of technical reviews. Technical assessment activities discover deficiencies or anomalies that often result in the application of corrective action. A structured review process should demonstrate and confirm completion of the required accomplishments and exit criteria as defined in both the program and system planning. Technical reviews are conducted throughout the life cycle development of the systems and are important in measuring the maturity of the system and whether continuation to the next phase is viable.

How are the requirements management aspects being handled by the contractor (traceability, use of tools, etc)? Requirements Management provides traceability back to user-defined capabilities as documented through the Joint Capabilities Integration and Development System. The program manager should institute Requirements Management to (1) maintain the traceability of all requirements from capabilities needs, (2) to document all changes to those requirements, and (3) to record the rationale for those changes. Emerging technologies can influence the requirements in the current as well as future increments of the system.

One of the biggest areas of concern is risk management and what are the technical risks. Risk management is critical to acquisition program success. The purpose of addressing risk on programs is to help ensure program cost, schedule, and performance objectives are achieved at every stage in the life cycle and to communicate to all stakeholders the process for uncovering, determining the scope of, and managing program uncertainties. Since risk can be associated with all aspects of a program, it is important to recognize that risk identification is part of the job of everyone and not just the systems engineer or program manager. The risk management process is continuously accomplished throughout the life cycle of a system. It is an organized methodology for continuously identifying and measuring the unknowns; developing mitigation options; selecting, planning, and implementing appropriate risk mitigations; and tracking the implementation to ensure successful risk reduction. Primary metrics used by the SEs for assessing technical risk are the Technical Performance Measures (TPM) that looks at selected data over time to analyze that the contractor is making against the design specifications

A configuration management process guides the system products, processes, and related documentation, and facilitates the development of open systems. Configuration Management efforts result in a complete audit trail of decisions and design modifications. The systems engineer must be competent in configuration management so that he can ask if the contractor is following a well defined Configuration Management

Plan.This would include progress toward meeting technical plan schedules and costs; technical progress toward satisfying the life cycle phase exit criteria; and the effectiveness of technical work completed.

Another systems engineering concern is the area of interface management. The question of have the integration of the various pieces or subsystems been adequately defined and are they functionally viable? This is an area I believe that both the government and contractor SEs must work together on to achieve success. There are several automated tools used for interface management but also needed on that list is some non-automated tools such as N2 Charts and work breakdown structures.

Finally, for the government engineer's technical management approach there is a need to assess the contractors technical data management approach that is used to plan for, acquire, access, manage, protect and use data of a technical nature to support the total life cycle of system being developed. This includes the development, deployment, operations and support, eventually the retirement and retention of appropriate technical data beyond system retirement as required by law. How this is all organized and orchestrated is helped by modern communications technology and teaming efforts such as Integrated Product Teams (IPT).

A key difference between the government and the contractor IPTs is that the purpose of the government IPT is to use the team as a management schema and the contractor is to technically design and build a system. Both IPT approaches must share data/information between them so that their respective Program Managers aren't suddenly surprised at a preliminary or critical design review. Both government and Industry must have SEs that are competent in what they do. Attempting to make that happen is best accomplished by education and on the job training of the workforce.

In addition to the Technical Management competencies listed above the developers of the enclosed table had the following areas as additional competencies: specifications, Earned Value Management, IMP/IMS, Technical Reviews, Software Engineering, and Systems Engineering by phases. All of these competencies are important as well as the ones I have discussed in this presentation.

## Position Paper for Panel 304

## What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency

| Technical Competencies | | | | | |
|---|---|---|---|---|---|
| **Analytical** *SE Tools & Techniques* *Design Considerations* | | **Technical Management** *Technical Management Processes* | | **General** *Total Systems View* | |
| 1 | Technical Basis for Cost | 21 | Decision Analysis | 36 | Acquisition |
| 2 | Systems Engineering Plans | 22 | Technical Planning | 37 | IPPD |
| 3 | Work Breakdown Structure | 23 | Technical Assessment | 38 | Leadership |
| 4 | Value Engineering | 24 | Requirements Management | 39 | International Acquisition |
| 5 | Technical Performance Measurement | 25 | Risk Management | 40 | Professional Ethics |
| 6 | Trade Studies | 26 | Configuration Management | | |
| 7 | Modeling and Simulation | 27 | Technical Data Management | | |
| 8 | Failure, Modes, Effects &Criticality Analysis | 28 | Interface Management | | |
| 9 | Requirements Traceability Matrix | 29 | Technical Data Packages | | |
| 10 | Safety Analysis | 30 | Specifications | | |
| 11 | SE Design Considerations | 31 | Earned Value Management | | |
| 12 | Requirements Development | 32 | IMP/IMS | | |
| 13 | Logical Analysis | 33 | Technical Reviews | | |
| 14 | Design Solution | 34 | Software Engineering | | |
| 15 | Implementation | 35 | Systems Engineering by Phases | | |
| 16 | Integration | | | | |
| 17 | Verification | | | | |
| 18 | Validation | | | | |
| 19 | Transition | | | | |
| 20 | System Assurance | | | | |

| Professional Competencies | |
|---|---|
| 41 | Communication |
| 42 | Analytical Skills |
| 43 | Decision Making |
| 44 | Problem Solving |
| 45 | Technology Management |
| 46 | Team Building |
| 47 | Influencing and Negotiating |
| 48 | Interpersonal Skills |
| 49 | Strategic Thinking |
| 50 | Understanding Attributes of Evidence and Rational Decisions |

*From the US DoD SPRDE Expert Panel Preliminary Competency Framework

# Position Paper for Panel 304

# What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency

**Panelist:** **Samantha Brown, BAE Systems**
**Topic: "A UK competency model and its role in achieving professional recognition."**

## UK Background

All engineering-based professions in the UK are regulated by the Engineering Council UK ($EC^{UK}$), an organisation set up by Royal Charter. It achieves regulation by working through 36 engineering institutions, providing the standard for assessment of individuals, for education programmes and for professional development programmes throughout the UK and in a number of other countries. Each of these engineering Institutions are known as Licensed Members, licensed to put suitably qualified individuals onto one of three sections of $EC^{UK}$'s Register of Engineers: Chartered Engineer, Incorporated Engineer and Engineering Technician. These titles are protected by the Engineering Council's Royal Charter and may only be used by registrants. Similar arrangements apply for other scientific disciplines.

Registration as a Chartered Engineer, Incorporated Engineer or Engineering Technician requires an individual to satisfy the competence standards set by $EC^{UK}$ in a standard known as UK-SPEC. Applicants must show that they have a satisfactory educational base, have undergone approved professional development, and, at interview, must demonstrate their professional competence against specific criteria in five key areas. Each Licensed Member or Institution interprets the competency requirements for their own discipline.

Those systems engineers in the UK wishing to be professionally recognised currently seek registration through one of the Licensed Members. In so doing, they must therefore demonstrate compliance with the interpreted competency requirements of that Institution. For a number of reasons, becoming a Licensed Member of $EC^{UK}$ is not an option for INCOSE UK. There is already a strong push from UK Government to reduce the diversity of designations in the engineering profession, and the infrastructure requirements and annual cost of licensed membership will be prohibitive for the foreseeable future. As an interim measure, INCOSE UK became a professional affiliate to $EC^{UK}$ in 2007, enabling the organisation to "buddy" with licensed Institutions in order to achieve registration for INCOSE members.

## Development of a UK Competency Framework for Systems Engineering

Recognising that the development and recognition of engineers and scientists in the UK is essentially competency-based, INCOSE UK launched an initiative to establish a competency framework for systems engineering in 2002. The aim was the establishment of a framework which could achieve national recognition through demonstrated value to organisations and employees, by defining the systems engineering capabilities required by both individuals and teams. Alignment with UK-SPEC was not an explicit requirement at this stage.

The focus of the activity was to develop a measurable set of competencies for systems engineering, **not** for systems engineers. This subtle distinction aimed to ensure that the work identified the competencies associated with the generic systems engineering role, without defining the way in which that might be implemented in an organisation or expanding into the broader engineering and leadership competencies which are already addressed within UK-SPEC.

## Position Paper for Panel 304

## What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency

The Systems Engineering Competencies Framework[1] and the associated Guide to Competency Evaluation have attracted considerable interest from both industry and Government throughout their development and implementation. They have become embedded in a number of large companies and government bodies as part of internal development frameworks for systems engineers, and further developments of the generic Framework continue to attract broad support from INCOSE UK Advisory Board members.

The Framework defines systems engineering ability as comprising:

- Competencies
- Supporting Techniques (the skills and techniques required to carry out systems engineering tasks, including a range of modelling and analysis techniques)
- Basic Skills and Behaviours (the common attributes including communication skills and teamworking required by any professional engineer, although typically needed as particular strengths by systems engineers)
- Domain Knowledge (the knowledge of industrial context, commercial environment and technologies which varies from industry to industry)

The Framework focuses on the Competencies and provides only examples in the other areas.

**<u>Systems Engineering Competencies</u>**

The Competencies which are predominantly associated with systems engineering are grouped into three themes:

- *Systems Thinking*, which contains the underpinning systems concepts and the system / super-system skills including an understanding of the enterprise and technology environment.
    - *Systems concepts*
    - *Super-system capability issues*
    - *Enterprise and technology environment*
- *Holistic Lifecycle View*, which contains all the skills associated with the systems lifecycle from need identification through to operation and disposal.
    - *Determine and manage stakeholder requirements*
    - *System design:*
        - *Architectural design*
        - *Concept generation*
        - *Design for …*
        - *Functional analysis*
        - *Interface management*
        - *Maintaining design integrity*
        - *Modelling and simulation*
        - *Select preferred solution*
        - *System robustness*
    - *Integration & verification*
    - *Validation*
    - *Transition to operation*

[1] The Systems Engineering Competencies Framework is available to download from the INCOSE UK website.

- *Systems Engineering Management*, which deals with the skills associated with selecting an appropriate lifecycle, and the planning, monitoring and control of the systems engineering process.
    - *Concurrent engineering*
    - *Enterprise integration*
    - *Integration of specialisms*
    - *Lifecycle process definition*
    - *Planning, monitoring and controlling.*

Each Competency is assessed in terms of levels of comprehension and experience as follows:

- *Awareness*, where the person is able to understand key issues and their implications. This level is aimed at roles which interface with systems engineering in the enterprise.
- *Supervised Practitioner*, where the person understands the subject but requires guidance or supervision. This level is aimed at engineers in training, or those working in a new area.
- *Practitioner*, where the person has a detailed understanding of the subject and is able to provide advice and guidance to others.
- *Expert*, where the person has extensive applied knowledge and practical experience, and acts as a point of reference for others in the organisation.

For each Competency, effective indicators are given for each of the four levels.

**Future Direction**

Professional recognition of systems engineers in the UK relies on establishing a route to engineering registration through a UK-SPEC compliant route, or similar competency-based routes in related disciplines such as physics or computer science. Work is ongoing within INCOSE UK to achieve this alignment, in parallel with the ongoing refinement of the competency framework itself based on experience with its use in a number of organisations over the past few years.

**Position Paper – What Defines a Systems Engineer**
**Systems Engineering in a Global Services Environment in the IT Services Industry**

Panelist – Mark Kupeski, IBM Corp.
Topic- Systems Engineering Competency Models

Systems Engineering has often traditionally been characterized by a product centric view of the discipline and the profession. Systems have been characterized by products (e.g. computer systems, automobiles, spacecraft, communications systems) or systems developed for unique purposes such as military or civil systems intended for specific purposes (e.g. control systems, navigation systems, etc.). As the global IT industry continues to evolve in complexity and the need for IT development becomes increasingly intertwined among software, hardware and process the notion of systems engineering and its application to information technology is also changing.

The global IT Services business has long been dominated by "application development" and "out-of-the-box" mindsets which recognize the need for Systems Engineering discipline, but often resist the implementation of systems engineering rigor and execution to address complex solutions. As custom development, package implementation and service oriented architecture meld into a complex systems framework, the need for and even the definition of what constitutes a systems engineer is broadening.

Systems Engineering in an IT Services Environment presents unique challenges that differ from Systems Engineering implementation in product or system development applications.

What defines a system in the IT and IT services industry?

The definition of a "System" in the Services Industry can be extremely diverse and involve considerations not as frequently dealt with in other industries. A services Systems Engineering implementation is not necessarily more complex than application of Systems Engineering to more traditional environments, however the problem is often less well defined and the complexities are different in nature.

- System context often includes elements of an enterprise IT environment including legacy and new hardware to deploy the infrastructure and a comprehensive enterprise application portfolio consisting of legacy systems, Services Oriented Architecture concepts and ISV software applications. While this definition is not necessarily any more broad than other systems problems, a key aspect of the challenge of the system engineer is this environment involves engineering the system with what is often an evolving and at times an incomplete problem definition.
- The global nature of systems development often requires working across multiple languages, cultures and time zones, challenging the systems engineer to establish context and to the maximum extent possible forcing standardization to minimize cultural differences and more importantly remove language and translation issues from requirements elaboration.
- Services environments stretch traditional Systems Engineering beyond new systems development, building on often marginally documented legacy systems and requiring

detailed planning and at times reverse engineering to establish requirements and verify consistency with business processes.
- Integration must address both functional and technical requirements as well as business implementation and physical and time phased (release planning) partitioning also take on increasingly important roles.

Deployment of a Systems Engineering competency in a services environment requires careful organizational planning and organizational capability development. Systems Engineering fits well with services, but must address:

- Development cost considerations
- Implementation/development by global organizations of components which must be effectively integrated often via remote interactions and testing
- Configuration of existing software solutions
- Effective design and optimization of software packages with custom developed software
- Non-functional requirements that often create complexities with regard to distributed environments and systems
- Tight integration of business processes with IT implementation
- Local and distributed teams to address local language and cultural issues and “delivery” or development organizations that leverage process and development standardization to enhance delivery quality and minimize cost through standard process and software assets
- Adaptation of Systems Engineering tools and methods to a services model in a software centric environment, but capturing requirements broadly defined from business process considerations to resulting service implementation requirements, as well as, the technical implementation of the hardware and software systems
- Implementation of a standard approach across multiple organizations requires a flexible implementation model
  - Must address technical complexity, systems architecture and technical management planning to address the overall design and development process.

A services implementation requires an approach to managing skills and certification

- Required to assure clients that skills in addition to designs, assets and processes are controlled
- Required to ensure skills of the team are sufficient to address the complexities of the system design and development

A Systems Engineer in the Services Industry is defined by:

- Systems Thinking - defining and bounding problems that are expressed in business terms, but are implemented as systems
- Ability to optimize a solution with often ambiguous or incompletely defined parameters and constraints
- Full life cycle thinking including the ilities
  - Availability, Reliability, Capacity and Security are key elements in addition to overall performance engineering
- Ability to develop incremental and release based implementations that maximize value and minimize risk
- Solving problems utilizing diverse teams in a global environment

- Flexible solutions that can be altered throughout development without major impacts
- Ability to solution and engineer in brownfield and greenfield environments

Flexibility, broad business acumen, technical strength and an ability to improvise are key characteristics, leading to the conclusion that a Systems Engineer in the services industry is defined by technical breadth and an ability to work and thrive on bringing order and structure to the architecture, design and development processes of complex solutions.

# Position Paper for Panel 304

# What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency

Position paper by

U Dinesh Kumar
Indian Institute of Management Bangalore
Bannerghatta Road, Bangalore 560076
dineshk@iimb.ernet.in

Systems engineer is a "*solution provider*" to problems that arise in engineering, management and public policy by creating a synergy between many functional areas of engineering, mathematics and management. Irrespective of regional differences, the role of systems engineer would remain as a solution provider. Systems used by us are becoming more and more complex everyday due to multiple functions bundled into the systems. Integration of several functions in to a single system obviously demands expertise from multiple disciplines of science, engineering and management. Systems engineering curriculum is suppose to equip the systems engineers with competencies required to meet the customer requirements (most often delight the customers) in an optimal way. There is no doubt about the need for systems engineering competency, although there is a need to debate what the competency is? In the next paragraphs, I have written systems engineering competency from an emerging markets perspective.

Emerging markets such as India, China and Brazil have unique problems that are not relevant in developed countries such as lack of infrastructure, access to advanced technology and off course systems engineers. It is surprising to note that India produces approximately 350,000 engineers but none of them are trained in systems engineering. No Indian university/institute has dedicated systems engineering graduate program. In my opinion, the situation in other emerging markets is not much different from India. One of the main reasons for lack of systems engineers in India is the lack of understanding of the role of systems engineers among corporate India. India till 1990s depended on imported technology and thus never felt the need for systems engineering skills. However, post liberalization, many Indian companies, especially the public sector companies started developing their own products and unfortunately had to train their employees in systems engineering skills to manage the project. Project such as light combat aircraft (LCA) by aeronautical development agency (ADA) and the civilian aircraft SARAS by national aeronautical agency (NAL) were probably delayed due to the fact that India never produced any trained systems engineers that was necessary for such projects.

The role of systems engineer is likely to be more challenging in emerging markets such as India due to the following reasons:

1. Lack of access to advanced technology.
2. Poor infrastructure.

On the other hand, it is expected that emerging markets such as India and China are likely to have major impact on world development and it is absolutely important that systems engineering competencies are understood clearly and developed in these economies. From an emerging markets perspective, systems engineer should have the following competencies:

1. Ability to provide optimal solutions under technological and infrastructure constraints.
2. Ability to design, develop and sustain complex systems under continuous technological skills.
3. System integration competencies.
4. Ability to lead multi-cultural teams.
5. Ability to make better decisions through quantitative reasoning.

Although there may be a need for some additional skills for systems engineers in different regions, the overall competency of systems engineer would remain as an interdisciplinary discipline that finds optimal solutions to complex problems.

# Position Paper for Panel 304

# What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency

### Australian Position Paper on Systems Engineering Competencies

**Stephen Cook, University of South Australia**

*Drivers for the change in the formation of systems engineers in Australia*

The formation of systems engineers in Australia followed a traditional experiential path until the mid 1990s: they largely learned their profession through an accumulation of substantial project experience acquired over many years. Several things changed in the mid 1990s. Firstly, by this time, Australian defence industry had moved almost completely towards a systems integration focus rather than a product-development focus; a change supported by Defence Industry Policy (DIP, 2007). This had two effects: it created greater demand for systems engineers, and it curtailed the opportunities for engineering staff to develop the discipline-focussed technical skills that characterise the early career of a systems engineer (RAE, 2007a). The second factor was the release of a number of seminal reviews and plans that highlighted that a good proportion of the problems encountered in major projects could be ameliorated through improvements to systems engineering practice (e.g. DPR, 2003; DESSPD 2004). This led to the formation of university-based, systems engineering research and education centres sponsored by both the Department of Defence and by State Governments (Cook et al., 2006). The third factor that has been driving change in the formation path has been the well-publicised increase in Australian defence capital equipment spending, in particular in the electronics systems area that in 2006 was expected to grow by 46% by 2010/11 (DCP, 2006; Cropley and Campbell, 2007). These factors combined have fuelled the need for considerably more systems engineers and have opened debate on what constitutes a systems engineer, how best to accelerate the formation process, and whether the new formation routes are effective.

*Shapers of the formation of systems engineers in the present era*

Postgraduate education for systems engineers in a university context has been well established overseas for a very long time. While programs have been available in Australia, they have been operating at a very small scale up until the last decade because of a number of factors. The first of these relates to the higher education funding arrangements in place in Australia both now and in the past. In the mid 1970s, university fees were abolished in Australia and the Australian Government paid all the fees in the then entirely public tertiary education sector. This happy position continued for over 15 years and created a generation of people that considered university education to be a right; one for which they were not expected to contribute directly. These funding arrangements became unsustainable as the participation rates expanded by a factor of six over the last thirty years and progressively fees for undergraduate degrees were introduced and have continued to grow until the present day when students now pay around one third of the cost of their education. There are loan mechanisms in place to facilitate this and fees have not impacted participation rates for first degrees which stand at around 30%; a figure mooted to rise to 40% (RAHE, 2008). The situation is quite different for higher degrees which also became subject to fees in the l990s. Uptake rates of postgraduate programs or second bachelor's degree are at relatively low levels and only around 20% of engineering graduates hold a qualification beyond a bachelor's degree (Kaspura, 2008) and only around half of these advanced qualifications are in technical areas. The first reason for this is simple, postgraduate degrees often attract full fees and as such are very unattractive to professional staff who either do not think it appropriate to pay for tertiary education or who are still paying for their first degree. The second reason is that a four-year Engineers-Australia-accredited degree (almost all engineering degrees are accredited in Australia) is recognised throughout the world via the Washington Accord as an appropriate academic qualification to enable one to practise as a professional engineer. Higher degrees are neither accredited nor are they in demand in many workplaces. The third reason is that higher technical qualifications are not often needed because industrial research and development spending in Australia languishes at the bottom of the OECD statistics. Thus, traditionally, higher degrees are only sought in certain industry sectors e.g. academia (where engineering academics are expected to hold a doctorate), government research laboratories, and the armed services.

# Position Paper for Panel 304

## What Defines a Systems Engineer? Comparing and Contrasting Global Perspectives on Systems Engineering Competency

It has been recognised for a few years now that government action is required to avoid a shortage of engineers in Australia (Kaspura, 2008) and particularly in defence-related systems integration skills (DESSPD, 2004; O'Neil et al., 2006; Cook et al., 2007). Indeed this action has been taken and it has come in several forms: the advent of employer sponsored engineering programs; funding of research in systems engineering and integration departments in universities, and the advent of numerous initiatives to reverse the decline in Science, Technology, Engineering and Mathematics (STEM) education in high schools.

*Competency requirements for Australian systems engineers*

The University of South Australia has been active in the provision of postgraduate programs for specific client groups in recent years. The first program commissioned was the Defence Science and Technology Organisation Continuing Education Initiative that comprises a flexible program to provide advanced masters-level education to defence science staff in a range of disciplines. This employer-sponsored program pays student fees for those students selected to participate. An introductory systems engineering course is mandatory for all streams and the system engineering stream has proven popular. DSTO is Australia's joint service defence science laboratory and it has the following mission: "DSTO is the Australian Governments lead agency charged with applying science and technology to protect and defend Australia and its national interests." DSTO supports Australian defence by investigating future technologies for defence applications, ensuring Australia is a smart buyer of defence equipment, developing new defence capabilities and enhancing existing capabilities by increasing operational effectiveness, improving safety, maximising availability and reducing the cost of ownership. DSTO's prime role no longer includes the design of equipment and the integration of systems to be delivered to the Australian Defence Force. Rather it seeks very high levels of competency in its people in areas relating to the support of both the acquisition community and the military customer and, as such, DSTO appointed an academic panel comprising senior representatives from each division to work with representative from the university to devise a suitable program. The DSTO program is strong on systems concepts, systems research, operational analysis, modelling and simulation, test and evaluation and supporting and evolving existing systems. Thus a successful systems engineer in the DSTO context is a rather differently skilled individual than one that would be required by industry or the acquisition community. Further insights from designing and delivering this program can be found in Kasser et al (2004).

In order to enable comparison of competencies framework both in Australia and overseas, I used the competency titles found in the INCOSE UK Systems Engineering Competency Framework (INCOSE UK, 2006) and attempted to map the priorities for DSTO educational outcomes against the competencies listed. These appear in Figure 1.

The same team of people at what is now the Defence and Systems Institute of the University of South Australia subsequently won a contract to deliver the Project Management Development Program to the Defence Materiel Organisation. This was also a masters program and was aimed squarely at middle-level acquisition executives. Once again these people were not required to design, build supply and maintain systems, rather their role is one of systems definition, requirements management, contract management and the overseeing of verification and validation. As before, the program was very much shaped by the customer and their subject matter experts. Once again, while all topics were touched upon, educational outcome priorities were not uniform and my impression of the priority profile is shown in Figure 1. It is well understood that educational outcomes are not the sole determiner of competency and DMO have been working on generating a competency profile for systems engineers for some time. The author is aware that it is liable to follow the US Department of Defense Acquisition, Technology and Logistics career path (ATL, 2007).

DASI has also been commission to provide systems engineering education to an industry consortium under the Skilling Australia's Defence Industry (SADI) Program. This is a Department of Defence skilling initiative that encourages and pays industry to identify their skilling needs and to work with an education provider who can design and then deliver a program to suit their needs. Thus the design of this program was, once again, driven by the customer. To facilitate this, a quality function deployment approach was employed to capture stakeholder needs and assist in the program design (Cropley and Campbell, 2007). This program continues to enjoy very strong industry interaction in its teaching and project work and is now being migrated to flexible delivery mode.

The author's impressions of the industry educational outcome priorities for this master's degree program are also illustrated in Figure 1.

It is clear that the profiles for the three groups are quite different.

**Table 1 Competency-base SE educational outcome priorities for different types of SE organisation.**

| | DSTO | DMO | Industry |
|---|---|---|---|
| **Systems Thinking** | | | |
| Systems concepts | **** | ** | *** |
| Super-system capability issues | **** | *** | ** |
| Enterprise and technology environment | *** | *** | **** |
| **Holistic Lifecycle view** | | | |
| Determine and manage stakeholder requirements | ** | **** | **** |
| System Design: | | | |
| Architectural design | *** | ** | ** |
| Concept generation | *** | ** | **** |
| Design for … | | | |
| Functional analysis | * | * | *** |
| Interface Management | * | * | **** |
| Maintaining Design Integrity | * | * | *** |
| Modelling and Simulation | **** | ** | ** |
| Select Preferred Solution | ** | ** | **** |
| System Robustness | * | ** | *** |
| Integration & Verification | ** | **** | **** |
| Validation | **** | **** | ** |
| Transition to Operation | ** | ** | ** |
| **Systems Engineering Management** | | | |
| Concurrent engineering | * | * | *** |
| Enterprise Integration | * | * | *** |
| Integration of specialisms | * | * | *** |
| Lifecycle process definition | * | *** | *** |
| Planning, monitoring and controlling | * | **** | **** |

*Accreditation of Systems Engineers in Australia*

The Systems Engineering Society of Australia has been discussing the accreditation of systems engineers for some time. To that end Hamilton combined all the issues into a paper that was presented as a keynote in the 2007 conference (Hamilton, 2007). This has since led to the formation of a Special Interest Group that is to further the conversation and make recommendations on the way forward. Hamilton makes the point that accreditation is all about competency assurance and hence has to be performed against a framework for the various levels to be awarded. In this substantial paper he compares the US certification approach against the UK and Australian chartered engineer approach that looks at educational formation, responsibility level achieved, and workplace-based knowledge among other things. For the latter, the applicant is required to keep a log book to record experience and undergo one of more interviews by an examining panel. It is unusual for an engineer to reach chartered status in less than ten years and it usually occurs after the individual has reached team-leader level. This approach is well able to deal with the reality that engineers from different sectors and roles will possess different competency profiles.

*Summary*

If we chose to define an engineer as a professionally-qualified person who practices some aspect of engineering then it would follow that a system engineer is a person who practises some aspect of systems engineering, namely some of those activities listed in ISO 15288 and reflected in the INCOSE Systems Engineering Handbook. That covers a lot of people from project managers, through process improvement people, to architectural designers, to system test engineers. Across such a large range of roles it is interesting to consider what competency means. The UK framework has four levels: awareness, supervised practitioner, practitioner and expert.

I would suggest that everyone employed in a systems engineering environment should have 'awareness' of all aspects of systems engineering. Most would have higher levels of competency, commensurate with their job level, in several others. Systems engineering experts could be expected to have reached 'expert' status in one or more areas and 'practitioner' level in a good number. Thus, I suggest that competency is not an absolute characteristic but a profile much as a company can have a process profile matched to its particular set of activities.

*References*

ATL 2007, *Acquisition, Technology and Logistics Systems Planning, Research, Development and Engineering Career Path*, available at http://www.dau.mil/workforce/index.asp, last accessed 21 March 2009.

Cook S.C., Sciacca L., Bates B., Nandagopal D., Allison S., Shackleton D. and Yates A. 2006, "A National Approach to Systems Integration Skills Base Development in Australia", in *INCOSE 2006 – 16th Annual International Symposium Proceedings*, Orlando, FL, USA, July 2006.

Cropley, D.H. and Campbell, A.J., 2007, "Meeting the Need for Defence Systems Engineers", Proceedings of the 16th Annual International Symposium of International Council on Systems Engineering, INCOSE, San Diego, USA, 24 to 28 June, 2007.

DCP 2006, *The Defence Capability Plan 2006-2016*, Public Version, Australian Department of Defence.

DESSPD (2004), *Defence Electronic Systems Sector Strategy Plan*, Defence Materiel Organisation, Department of Defence.

DIP 2007, *Defence and Industry Policy Statement 2007*, Australian Department of Defence.

DPR 2003, *Defence Procurement Review 2003*, Australian Department of Defence.

DSIC 2008, *DSIC Submission to the Defence White Paper Considerations*, Defence Systems Innovation Centre.

Hamilton P., 2007, "A Discussion Paper – Systems Engineering Accreditation", in *Proceedings of the Systems Engineering and Evaluation Conference*, Sydney, Australia.

INCOSE UK, 2006, *INCOSE UK Systems Engineering Competency Framework*, INCOSE UK.

Kaspura, A 2008, *The Engineering Profession: A Statistical Handbook, Fifth Edition*, Institution of Engineers Australia, available at http://www.engineersaustralia.org.au/representation/publications/

Kasser, J.E., Cook, S.C., Larden, D.R., Daley, M. and Sullivan, P., 2004, “Crafting a Postgraduate Degree for Industry and Government”, in *Proceedings of the 2004 IEEE International Engineering Management Conference*, Singapore, 18 to 21 October 2004, pp 129 to133.

O’Neil M., Dewan E., and Whetton S., 2006, *Defence Industry Workforce Requirements: 2006-2010*, The SA Centre for Economic Studies.

RAE 2007a, *Creating Systems that Work*, ISBN 1-903496-34-9, The Royal Academy of Engineering.

RAE 2007b, *Educating Engineers for the 21st Century*, ISBN 1-903-496-35-7, The Royal Academy of Engineering.

RAHE 2008, *Review of Australian Higher Education*, Department of Education, Employment and Workplace Relations, Australian Government.