SYSTEMS ENGINEERING NEWSLETTER

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1. QUOTATIONS TO OPEN ON

"Engineering is 7.5% inspiration and 92.5% perspiration. Both are essential."

Robert John Halligan

"Injustice anywhere is a threat to justice everywhere."

Martin Luther King

"Strive not to be a success, but rather to be of value."

Albert Einstein

2. FEATURE ARTICLES

2.1 A Functional Workspace for Hospital Emergency Rooms

by

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Abstract

A functional workspace is a fully integrated and comprehensive information-action system in which information is structured in a manner that reflects the structure of the cognitive work. A functional workspace provides robust, accessible action modes and diverse action capabilities so that, once having assimilated the essential information for a work task, workers can act in response to it in naturally

compatible ways. Functional Workspace Design represents a paradigm shift in Human Systems Integration. Here we explain more fully what a functional workspace is, illustrate the concept by describing a prototype functional workspace for a hospital emergency department, and outline the advantages of using a functional workspace. Functional Workspace Design can enhance system performance in any information-rich socio-technical domain in which workers must find, organize, and interpret information as they decide and act.

Introduction

In a previous article published in PPI SyEN 66 (June 2018)[1], Gavan Lintern argued that an ambitious goal for Human Systems Integration is to develop a new form of joint human-technology system that is considerably more powerful than our current systems. To accomplish that, we must use technology to amplify and extend human cognition rather than to replace it. One important strategy is found in the development of a *functional workspace*, also known as a *functional information system,* an *ecological information system, or* an *ecological interface*.

Characterization of a Functional Workspace

A functional workspace provides a portal to all information that is potentially useful in a work environment and fully supports all essential activities. It is termed *functional* because the information it provides is mapped directly to the functions offered by the work environment and the task-oriented action opportunities it provides permit direct manipulation of those functions as a means of achieving work goals. A functional workspace is one in which information is structured in a manner that reflects the structure of the cognitive work so that workers can assimilate the information readily and then act on it in naturally compatible ways.

It might initially seem that the flood of information available through a functional workspace would result in cognitive overload. However, functional workspaces avoid that problem by exploiting symmetric displays and frames of reference that set information in context and draw attention to global issues in a manner that prompts workers to focus selectively on currently relevant details. Functional workspaces support cognitive performance by revealing the nature and complexity of operation of underlying system processes, the interactions between system states, and the constraints on action. On the activity side, they emphasize seamless and robust navigation between resources so that workers can converge naturally on momentarily important constellations of information. They provide robust, accessible action modes and diverse action capabilities via multiple-dimension controllers and direct, compatible action modes.

Within a functional workspace, information is structured in a manner that reflects the structure of the cognitive work so that workers can assimilate the information readily and then act on it in naturally compatible ways. The information is readily assimilable and there are natural transitions between information elements. The term *workspace* is preferred to *interface* or *information system* to emphasize that workers must remain fully

[1] "Human Systems Engineering as a Path to Transformation of Systems Capability." See https://www.ppi-int.com/ppisyen66/

immersed and supported in the work and should not be separated from it by the technology.

The vision for a functional workspace is one of a fully integrated and comprehensive information-action system. It is an electronic workspace that relies heavily on visualization and that employs many computerized means of transforming, selecting, highlighting, and associating information. Such a workspace employs icon libraries, work templates, drag-and-drop functionality, selection by mouse click, association by linking with mouse action, interrogation of concepts to bring up more detail or context, and convenient modeling tools to test outcomes of proposed actions.

In summary, a functional workspace has much in common with a natural workspace, one in which there are diverse and functionally relevant sources of information that can be explored and acted upon in diverse ways, thereby accommodating the variety, variability and demands of work. Such a workspace encourages workers to operate within a space of potential action, leaving them free to develop solutions to complex patterns of events that cannot be anticipated. It encourages a stronger appreciation of emerging issues and opportunities and promotes more robust and more accurate performance.

Application of a Functional Workspace in a Hospital Emergency Department

Many hospital emergency and surgical departments use wall displays in the form of white boards to track and update the status of patients. Increasingly, whiteboards are being replaced by electronic wall displays that mimic the functionality of the white boards. These new electronic wall displays do not, however, take advantage of the potential for computers to support cognitive work in new and innovative ways. In this article, we describe how the ideas surrounding a functional workspace can transform the functionality of electronic wall displays to address many of the significant cognitive challenges faced by clinicians and other healthcare workers in treatment of patients. Furthermore, a functional workspace can address many of the current information management issues that have been exacerbated by the introduction of electronic healthcare records (Lintern and Motavalli, 2018).

Figure 1 shows a prototype of a functional workspace for a hospital emergency department (Lintern and Motavalli, 2017). Clinical interaction with this workspace will be seamless. Contemporary healthcare technologies typically impose computer entry and management tasks on clinical staff, many of which are time consuming and cognitively effortful, thereby diverting clinicians from their clinical work into computer management tasks (Lintern and Motavalli, 2018). Functional Workspace Design exploits the principles of direct perception, direct manipulation, and ubiquitous computing to ensure that expert workers focus their attention on their cognitive work rather than on unintended demands of technology management. Clumsy, labor-intensive features such as data-entry windows, drop-down menus, lists with check boxes, and alarms are avoided in favor of seamless navigation between functional entities, drag-and-drop capabilities, voice and gesture commands, multi-sensory information systems, information entry via

Dialogue Management Systems[2], and numerous other design features that link naturally to human capability.

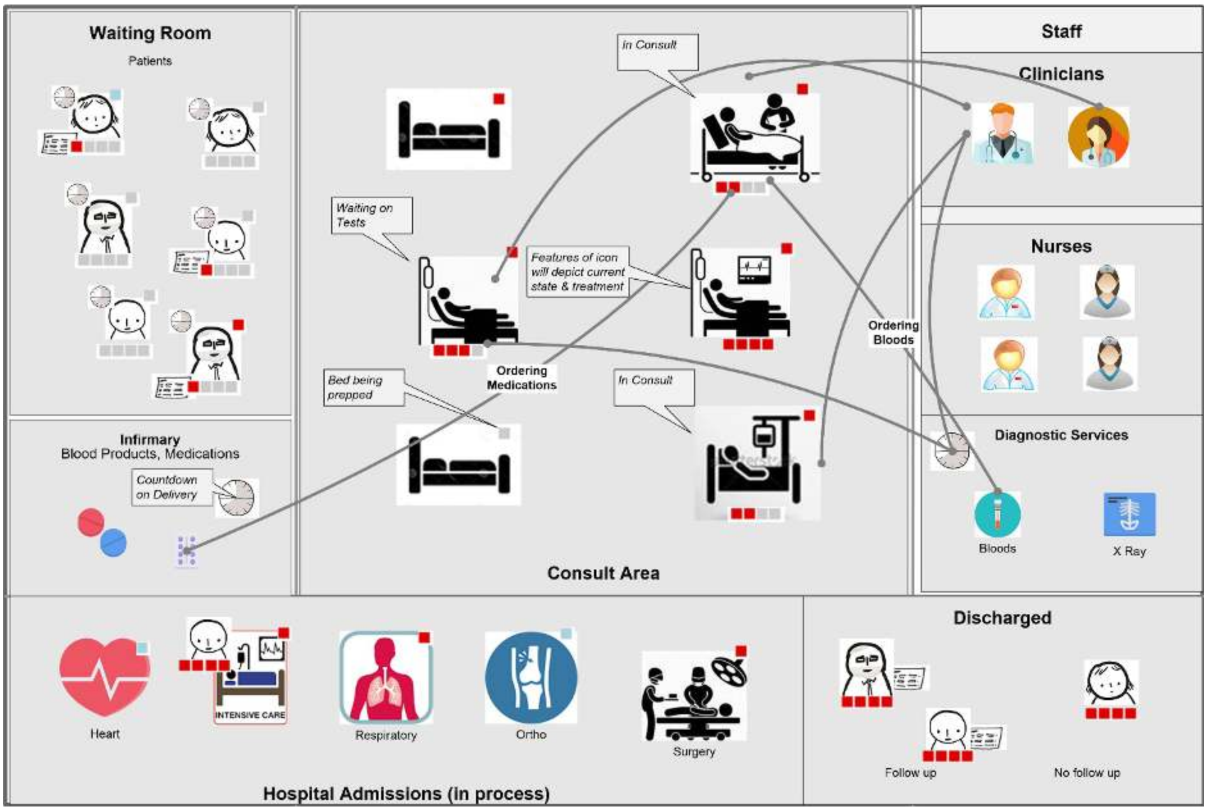

Figure 1: A prototype of a functional workspace for a hospital emergency department, depicting interactions resulting from clinician-patient encounters.

The vision is of an integrated work system comprised of a computerized wall display together with complementary Apps that reside on other hospital computers and on personal hand-held devices. The wall display, the hospital computers, and the personal hand-held devices will constitute nodes within a fully integrated, net-worked system, wherein the nodes will mirror user-selected functionality of the wall display and will also provide full functional support for information entry and for interrogation of information resources. The portals to the work system (the wall display and the Apps) will employ icon libraries, work templates, drag-and-drop functionality, selection by mouse click, association by linking with mouse action, interrogation of concepts to bring up more detail or context, and convenient modeling tools to test outcomes of proposed actions. The wall display and its complementary Apps will be developed in accordance with the characterization of a functional workspace provided above.

Preliminary Cognitive Analysis of Emergency Department Work

Following arrival at the emergency department, prospective patients are processed through a triage evaluation. Those with no apparent need for emergency care are encouraged to seek care elsewhere while the remainder are sorted into various streams and then treated depending on their triage evaluation. From Lintern and Motavalli (2017), there are several common concerns:

[2] A Dialogue Management System uses natural language processing to manage natural language interactions between humans and computers, thereby supporting human-computer interaction that is like normal speech interactions between humans. See https://en.wikipedia.org/wiki/Dialogue_system

- The most general issue is poor coordination between departments, resulting in part from conflicting agendas.

- Because of limited staffing, facilities, and funding, emergency departments typically operate at or near maximum capacity, giving clinicians little opportunity to reflect within their diagnostic work on challenging issues. To cope, clinicians develop their own strategies for organizing their workflow. For example, patient loads can create a mismatch between available resources and demand for care. To cope with resource-demand mismatches, clinicians often sort patients into separate queues that match need to available care types.

- Waiting times for patients can be so long that many patients leave without seeing a clinician. Also, patients can deteriorate while waiting to the point that immediate treatment becomes essential.

- Because care is often distributed among several healthcare professionals, coordination of care for individual patients can be inconsistent.

- The consulting clinician must elicit a patient history, including reconciliation of medications (which is known to be a challenging issue, Cook, 2017), and must take time out to enter that history into the computerized information system.

- Clinicians cannot anticipate when test results or medication orders will be returned and are not routinely advised of important abnormal results as they emerge.

- It can sometimes be difficult to find a suitable hospital bed for a patient who is designated for admission to a ward or an intensive care bed, which can result in the patient waiting in the emergency department for many hours, taking up valuable emergency-department bed space.

- Patients who are released to home or to the street are rarely followed up after release. Furthermore, means of ensuring that these patients understand their diagnosis and confirming that they understand their medication procedures or what they need to do to manage their condition are lacking.

These are a subset of the challenging cognitive issues faced by clinicians and other healthcare support staff within the emergency department. To resolve these challenges, the computerized functions of the workspace will be designed to reflect the cognitive structure of the problem so that those functions can be deployed seamlessly to support the clinical work. From Lintern and Motavalli (2017), we list potential solutions:

- **Admission and streaming**; an information dashboard that helps emergency department staff anticipate consult timing and resource allocation for current emergency patients and for those in the waiting room with diagnoses and who have been assigned a triage category.

- **Patient waiting times;** a summary displayed to patients in the waiting room showing likely wait times, to help inform their decision to stay or leave.

- **Monitoring of waiting patients**; an information dashboard of critical health parameters that displays the health status of waiting patients ubiquitously to emergency department staff.

- **Patient Record**; touch to bring up detailed patient information, based wherever available on the centralized national individual health record but organized and updated specific to the nature and state of the variety of patient conditions; recognize a clinician's ownership (and release) of a patient by monitoring duration (video) and content (speech recognition) of consultation; employ the latest developments in Natural Dialogue Systems (Sonntag, Huber, Möller, Ndiaye, Zillner and Cavallaro, 2010; Berg, 2014) to construct a patient history from the clinician-patient conversation.

- **Test results**; an information dashboard that allows a clinician to view the workload of the testing laboratory and other pertinent details such as number of technicians on duty, as well as the position of their tests in any queue, together with an estimate of the time that the results will be available for delivery (a countdown alert), and an indication of any interim result that suggests an important abnormality.

- **Orders for blood products and medications**; an information dashboard for processing orders for and delivery of surgical and non-surgical intervention resources (e.g., blood products, medications), similar to the dashboard developed for test results.

- **Resource-demand mismatches;** a workflow organization tool that helps clinicians match patient needs for care with available resources.

- **Patient follow-up**; patient contact details migrated automatically to a follow-up service that contacts patients within a specified period.

- **Location of a suitable bed**; a shared resource-constraint space, structured in terms of patient factors (subspecialty, severity, likelihood of need for certain types of care) with drag-and-drop input from the emergency department clinician, to show a suggested determination of which specialty unit or ward the patient should go to on the basis of current provisional diagnoses, past medical history, previous admissions and diagnoses, and prior agreed criteria by the specialty units for acceptance, together with current resource availability and constraints in that and other units or wards of interest.

Because emergency departments often operate at or near maximum capacity, it is essential that technology supports do not create additional tasks. They must be focused primarily on helping healthcare practitioners perform their cognitive work, particularly the work that is tactical and strategic. Time for reflection and planning is essential. Given the intensive nature of this work, cognitive supports that ease the load of routine work and that create opportunities for assessing, diagnosing, planning, and coordinating are likely to be well received by clinicians and are likely to enhance the quality of healthcare.

Advantages of Using a Functional Workspace

The design of a functional workspace leverages from the insight that the way in which a problem is represented has a profound influence on how easy or difficult it is to resolve (Bennett & Flach, 2011). This approach has gained considerable research traction in human interface design (e.g., Bennett, Bryant & Sushereba, 2018; Borst, Flach & Ellerbroek, 2015) largely inspired by an evocative and wide-ranging discussion from Vicente and Rasmussen (1992). It meshes with a current impetus in healthcare to develop visually rich information systems that support clinical work with dynamically updated summaries of evidence, health indicators, and treatment plans as they relate to best healthcare practice (Militello, Saleem, Borders, Sushereba, Haverkamp, Wolf and Doebbeling, 2016; Nemeth, Anders, Strouse, Grome, Crandall, Pamplin, Salinas and Mann-Salinas, 2016).

A functional workspace constitutes a paradigm shift for Human Systems Integration. It is naturalistic, eschewing inflexible, labor-intensive features such as data-entry windows, drop-down menus, inflexible templates, and check-box lists to leverage the powerful perceptual, thinking, and action capabilities we employ so effectively in our interactions with our everyday world. As a cognitive workspace for a hospital emergency department, it goes beyond the functional potential of a physical whiteboard to supplement clinical expertise and judgment in diagnosis and planning with seamless navigation to a supportive network of crafted, dynamically updated summaries of evidence, health indicators, and treatment plans as they relate to best healthcare practice.

While a functional workspace presents more information than a conventional interface, it does not overload the worker because that information is updated dynamically and integrated across levels of abstraction, and the workspace supports natural and compatible navigation that allows the worker to converge seamlessly on currently important constellations of information. Although a functional workspace reduces complexity of activity, it does not do that by reducing the complexity of the information but rather by managing the form by which that complexity is represented.

A functional workspace acts not only as an individual workspace but also as a shared workspace, and it is a shared workspace in two respects. First, in a collaborative system, a worker will often benefit from concurrent access to information about other parts of the shared work domain. As an anesthesiologist might glance at the progress being made by a surgeon as a means of anticipating an anesthesiologic intervention, it can be of value in collaborative environments for team members to remain aware of the status of work being undertaken concurrently by others. This not only supports individual reasoning, but also gives cooperating workers the opportunity to negotiate their individual contributions to common goals. Second, in sequential sharing of activities, information must be available about the activities of others (including designers and planners) at previous (and later) points in time, including the conditions of action and the objectives and criteria underlying earlier (and later) decisions. Such information will often have important implications for how workers satisfy their local constraints.

More generally, work practices are always both constrained and supported tactically and strategically by the available artifacts and resources. Developments in information technology typically assume that work revolves around data. Thus, technological development focusses largely on providing for data entry and data access. This approach is, however, limited. Much work is structured around physical artifacts which, by their appearance and location, act a reminders and as guides to thinking and collaborating (Xiao 2005). The loss of these artifacts through computerization is likely one reason that healthcare professionals who are often positive about the introduction of innovative technology become disenchanted when they discover that it disrupts their workflow (Lintern & Motavalli, 2018).

One principle of a functional work system is that its virtual objects be designed in such a way that they serve to support thinking and collaboration in much the same way as do physical artifacts. However, a virtual world is not subject to the normal constraints of the physical world, thereby providing the opportunity to support cognitive work in ways not possible with physical artifacts. Innovative cognitive interventions have shown huge gains in system performance when directed at selected problems (Lintern, 2011a; 2011b; Lintern, Moon, Klein, & Hoffman, 2018). The goal for Functional Workspace Design is to promote similarly huge gains in system performance across the entire spectrum of a targeted work domain.

Summary

A functional workspace offers a new and transformational way of engaging in computer-supported work. Although the illustration we discuss here focuses on a specific work domain, the concept can be generalized to any information-intensive work that places significant cognitive and coordinative demands on the work force. There is growing evidence that targeted support for cognitively challenging work offers significant potential for enhancing system performance. Functional Workspace Design applies that strategy system wide. The focus is on the cognitive work with an emphasis on how we might employ technological functionality to support that work. Functional Workspace Design uses formal methods of cognitive analysis and cognitive design to ensure that cognitive work is effective, efficient and robust. The aim is to amplify and extend the human capability to know, perceive, decide, plan, act and collaborate, by integrating system functions with the cognitive processes they need to support. The result with information-intensive work will be performance gains that exceed those possible with technology-focused solutions, thereby leading to much-desired gains in efficiency, productivity and safety.

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Gavan Lintern earned his Ph.D. in Engineering Psychology from the University of Illinois in 1978 and M.A. and B.A. degrees in experimental psychology from the University of Melbourne, Australia, in 1971 and 1969. He has worked in aviation-related human factors research at the Defense Science and Technology Organization (then known as the Aeronautical Research Laboratories), Melbourne (1971-1974), and in-flight simulation research on a US Navy program in Orlando, Florida (1978-1985). He returned to the University of Illinois in 1985 to take up a position as a faculty member at the Institute of Aviation (1985-1997). He has subsequently filled positions as head of human factors at the Defense Science and Technology Organization in Melbourne (1997-2001), senior scientist with Aptima, Inc in Boston (20012003) and chief scientist with General Dynamics Advanced Information Systems in Dayton Ohio (2003-2009). He now has an adjunct appointment at the Monash University Accident Research Centre.

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He has over 40 publications in reviewed journals and numerous symposium papers and book chapters. He is a Fellow of the Human Factors & Ergonomics Society, a recipient of the Jerome H. Ely Award, 1991, best paper in Volume 32 of Human Factors and a recipient of the George E. Briggs Dissertation Award, 1978. He has served on the Editorial Board, Human Factors (1986-2000) and still serves on the Editorial Boards of The International Journal of Aviation Psychology (since 1991) and Cognitive Engineering & Decision Making (since 2007).

Gavan retired from General Dynamics in early 2009 and now works part time as an industry consultant, trainer with PPI, otherwise filling in his time as minder of the home pets and general home roustabout. He published a book, *The Foundations and Pragmatics of Cognitive Work Analysis*, in April 2009 and another, *Joker One: A Tutorial in Cognitive Work Analysis*, in August 2013.

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2.2 The Impact of the Helix Project on Regent University's Undergraduate Systems Engineering Program

by

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Editor's note: See also the article concerning Regent University's new and unique undergraduate systems engineering program provided in the Academia and Education section of this issue of PPI SyEN.

Abstract

The Helix project, sponsored by the US Department of Defense (DoD) and performed at the Systems Engineering Research Center (SERC)[3], was initiated to understand what makes systems engineers effective. This project produced *Atlas: The Theory of Effective Systems Engineers*, and other artifacts to help individuals in charting a successful career path in systems engineering, and organizations to improve the effectiveness of their systems engineering workforce. An unintended yet valuable application of Helix's products was in a formal systems engineering educational program at a university.

This article discusses the impacts of the Helix project and its findings, in the development of a new undergraduate systems engineering program at Regent University, USA.

Introduction

The Helix Project (henceforth referred to as 'Helix') is a multi-year research project that was initiated in 2012 by the US Department of Defense (DoD) at the Systems Engineering Research Center (SERC), to address research questions concerning the effectiveness of systems engineers and the role of the organizations in improving it. Primary data for this study was collected through interviews with hundreds of systems engineers from various DoD organizations, contractor organizations of DoD, and other commercial organizations (Hutchison et al, 2016). The key researchers of Helix (two of whom have now moved on from the project) have packaged and presented the major findings and products of the project in *The Paradoxical Mindset of Systems Engineers,* a book designed and written for use by individual systems engineers, managers of systems engineers, organizations that employ systems engineers, and other engineers and managers who perform some kind of systems engineering activity (Pyster et al, 2018). These people were the subjects and intended beneficiaries of Helix from the beginning of the project.

A key differentiator of Helix, when compared to other similar efforts, has been the focus on the systems *engineer*, rather than on the discipline of systems *engineering*. Accordingly, organizations that employ systems engineers became a rich source of data for Helix, in addition to being recipients of the resulting findings and recommendations. Another type of 'organization' that deals with systems engineers is institutions of formal systems engineering education. Though they have not been explicitly identified as intended beneficiaries, universities that offer systems engineering programs can benefit greatly from Helix.

One such unplanned beneficiary of the Helix project is Regent University, located in Virginia Beach, USA, and its newly formed undergraduate program[4] in systems engineering. An attempt to derive value from Helix was not initiated by Regent, but was triggered when one of the lead researchers of Helix joined Regent to develop its systems engineering program. Groundwork and initial discussions began in 2015, and in 2016 Regent University made the decision and initiated formal procedures to launch an undergraduate program in systems engineering. While Helix did not play any role in Regent's decision

[3] The Systems Engineering Research Center (SERC) is a University-Affiliated Research Center (UARC) of the US Department of Defense. It leverages the research and expertise of faculty, staff, and student researchers from more than 20 collaborating universities throughout the United States. SERC is unprecedented in the depth and breadth of its reach, leadership, and citizenship in Systems Engineering. See https://sercuarc.org/

[4] Note that in the U.S., bachelor's degrees such as B.S. (Bachelor of Science) are considered to be undergraduate programs, and master's degrees such M.S. (Master of Science) are considered to be graduate programs. In some other countries, bachelor's degrees are considered to be graduate programs (or degrees), and master's programs are considered to be post-graduate programs (or degrees).

to launch this program, it has had a significant influence in the shaping of the program since summer 2017. The B.S. in Systems Engineering degree program was launched in fall 2018 with the enrollment of its first students.

Four Impacts of Helix on the Design and Development of Regent's Undergraduate SE Program

In the subsequent sections, this article discusses four key impacts of Helix on the design and development of Regent University's undergraduate systems engineering program: 1) justification for an undergraduate program in systems engineering, 2) graduating effective systems engineers, 3) establishing the path for a career in systems engineering, and 4) the role of mentoring in systems engineering education.

1. Justification for an Undergraduate Program in Systems Engineering

The validity of an *undergraduate* program in systems engineering continues to be a point of contention within the systems engineering community. Some hold a strong view that systems engineering should be offered only at the graduate (Masters) level and not at the undergraduate (Bachelors) level, and also recommend that the student spend a couple of years in industry before pursuing the graduate degree. A workshop on undergraduate systems engineering programs in the US was conducted in 2010. It resulted in high level observations and recommendations, but did not quite resolve the debate (1st Workshop on U.S. Undergraduate Systems Engineering Programs, 2010). Since 2010, many graduate programs in systems engineering have been established around the world, but the number of undergraduate programs has not changed significantly. However, there have been some new undergraduate programs in 'industrial and systems engineering' recently.

Helix interviews with systems engineers offered remarkable insights suggesting that undergraduate systems engineering programs are not only justified, but perhaps even necessary for the maturing and wider acceptance of systems engineering as a discipline. Interview findings included the following:

- Most of the systems engineers stated that the first time that they ever heard the term 'systems engineering' was in a work environment. Some systems engineers, especially those whose undergraduate degrees were from universities that offered systems engineering degrees, knew that such a discipline existed but did not know anything more about it at that time.

- It is uncommon for students in kindergarten through grade 12 to aspire to be systems engineers, because they do not know that such engineers exist. Early in their lives, they are exposed to a variety of professions and many tend to find one that is exciting and intriguing and they eventually become a professional in that field. There are many efforts, especially in the U.S., to excite students concerning a potential career in a STEM field (Science, Technology, Engineering, and Mathematics). Still, this does not increase awareness about systems engineering - as a discipline and as a career choice.

- Most engineers identify themselves with their undergraduate discipline, irrespective of the majors they choose for their graduate degrees. Some participants in Helix interviews, despite holding a 'systems engineer' title at their organizations, still considered themselves to be 'electrical engineers' or 'mechanical engineers'. Some other Helix participants who considered themselves to be systems engineers, would also say something to the effect of: "*I am basically an aeronautical engineer and started that way in the industry. Then I got into systems engineering because…*". It was rare to find a systems engineer who *entered* the industry as one – they almost always *became* one.

An undergraduate program in systems engineering potentially could help address some of the issues. High school students looking to decide on the discipline to pursue for the undergraduate degree are likely to get exposed to the existence of systems engineering as a major; and if they seek more information, they are likely to pursue it if it interests them. Those students who go on to obtain an undergraduate degree in systems engineering are more likely to *enter* the industry as systems engineers. Regent's undergraduate program in systems engineering provides such a challenge and opportunity. After 40 years of existence since starting as an institution of higher learning (offering graduate programs), and then beginning to offer undergraduate programs about 10 years ago, Regent is now entering the world of engineering education with systems engineering as one of two engineering programs (the other being computer engineering). Hence, even to those who may be familiar with Regent University otherwise, engineering programs at Regent are relatively unknown – that is the challenge. The opportunity is that systems engineering at Regent is likely to get more visibility than in other universities that offer an undergraduate program in systems engineering since it is one of only two engineering programs, currently. Even with other engineering programs likely to be launched in the coming years, systems engineering would always be one of the first two engineering programs ever, at Regent.

2. Graduating Effective Systems Engineers

The major product of the Helix project is *Atlas: The Theory of Effective Systems Engineers*. At the center of this theory is a Proficiency Model with the following six areas that are further subdivided into Categories and Topics, as shown in Figure 1:

1) Math/Science/General Engineering
2) System's Domain & Operational Context
3) Systems Engineering Discipline
4) Systems Mindset
5) Interpersonal Skills
6) Technical Leadership

For any systems engineer (or even for someone who is not a systems engineer), a Proficiency Profile can be created, that reflects their level of proficiency in all six of these proficiency areas. Figure 1 also includes a sample Proficiency Profile. Proficiency profiles can also be created at the category level for each of these six areas.

While the objective is not to prescribe a universal scale for quantifying proficiency or to define any 'minimum' proficiency profile that would distinguish an effective systems engineer from one who is not, this is a valuable tool to identify strengths and areas for improvement. The individual systems engineer could then go on to improve their proficiency profile through a variety of initiatives, with the support of their leadership and organization. From a Helix project perspective, the target 'systems engineer' for such an exercise was the systems engineer employed at an organization. At Regent University, the target systems engineer is the student of systems engineering, and the undergraduate program utilizes this proficiency profile in two ways.

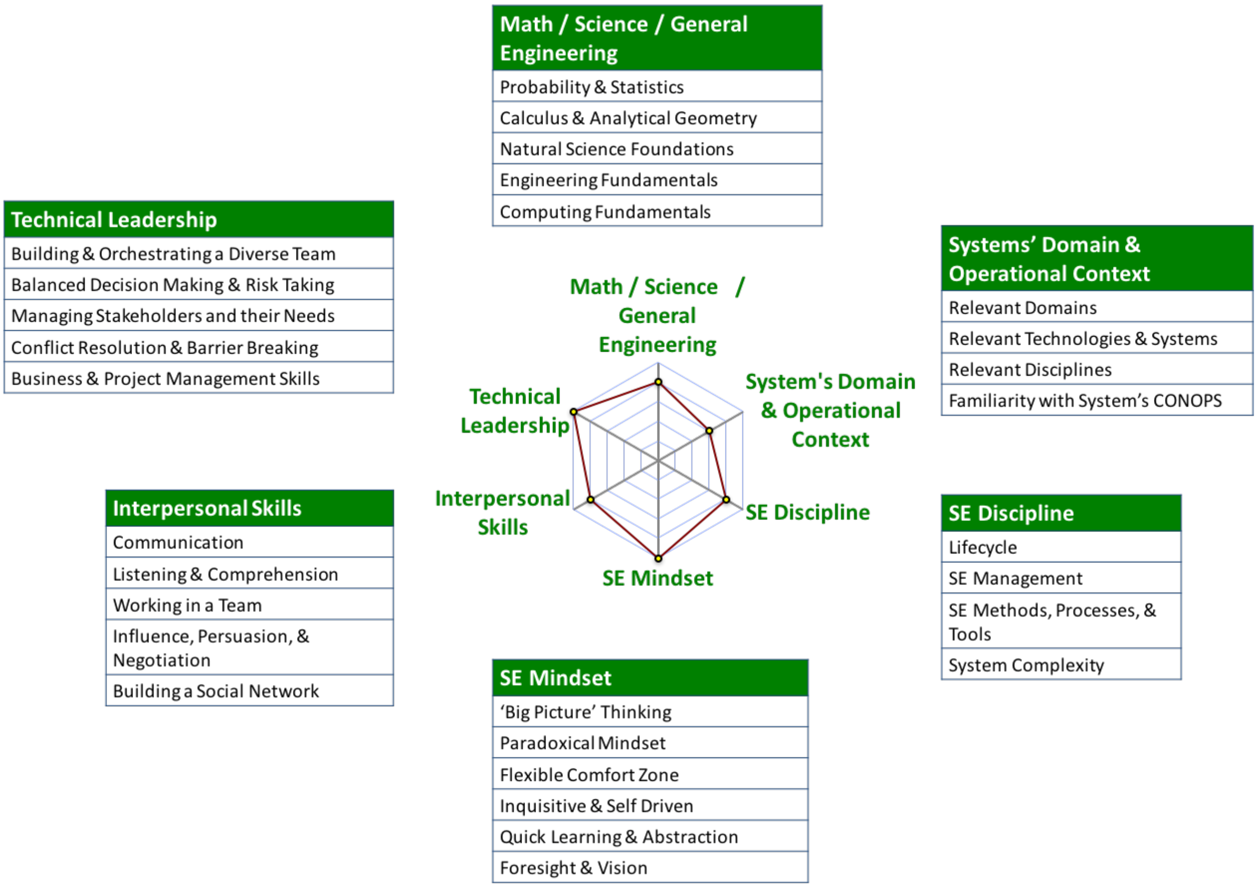

Figure 1: Proficiency Model (showing Areas and Categories) and Example Proficiency Profile

First, a primary objective of the undergraduate curriculum is to provide adequate coverage in all six proficiency areas. The courses and the topics to be covered under each course have been identified based on this objective. Higher level courses that build upon lower level courses are designed to help increase the proficiency level of the student in the corresponding proficiency areas and categories. A four-year undergraduate program in systems engineering offers the scope to cover a wider range of proficiencies, and could thereby produce a holistic and effective systems engineer. In comparison, a two-year graduate program is constrained by the number of courses that can be included in the curriculum.

Secondly, students of Regent's undergraduate program would create their own proficiency profile (through discussion with a faculty member) at least twice during their program: first towards the end of their junior (3rd) year, and then again towards the end of their senior (4th/final) year. When they do it the first time, it would expose them to where they stand with respect to the Atlas proficiency model, and identify the areas that they need to work on. During the summer between the Junior and Senior years, students are expected to obtain some industry experience through internships or other means. In the senior year, all students would be working on their capstone projects. While they are doing these, students would be seeking to improve their proficiency profiles; this is expected to provide a motivation for them to actively engage and learn. The capstone projects will be a two-course sequence provided through the entire academic year, and is designed to provide sufficient opportunity for students to improve their proficiency profiles. At the time of graduation, a student's Proficiency Profile might look like the illustration in Figure 2. Creating their proficiency profiles for the second time before graduation facilitates them to evaluate their 'growth' as a systems engineer during the undergraduate program, and in identifying their strengths in specific areas. Students will be encouraged to utilize this proficiency profile during job interviews; and companies that employ systems engineers who may already be familiar with Helix would be able to quickly appreciate the strengths of the potential employee.

Not all of the proficiency areas, particularly the categories and some specific topics, can be effectively presented in courses taken for credit. Being aware of this, the student would be provided opportunities to acquire and hone specific skills and abilities through co-curricular and extra-curricular activities led by the systems engineering faculty, department, and university; and also during summer internships in industry.

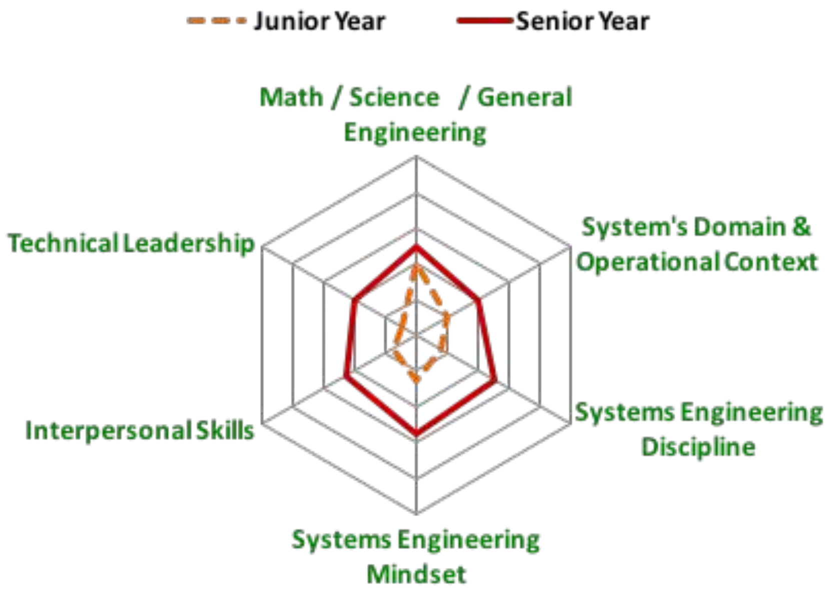

Figure 2: A Student's Sample Proficiency Profile

3. Establishing the Path for a Career in Systems Engineering

Another key artifact developed during Helix is the "Career Map", which helps visualize the career of a systems engineer. The Career Map (illustrated in Figure 3) captures educational milestones, organizational milestones and titles, organizations worked at, number of systems engineering positions held, roles[5] performed (out of the 15 identified by Helix), exposure to lifecycle phases, and Proficiency Profiles at different points in the career of the systems engineer. Helix has analyzed the Career Maps of various senior systems engineers (Hutchison and Verma, 2018), to obtain patterns and insights. Systems engineers, wherever they may be in their careers, can use the Career Map to reflect on their career journeys thus far, and to then be intentional in choosing upcoming projects and programs, and to make career-related decisions. Managers of those systems engineers could use the Career Maps for evaluation and workforce planning purposes as well.

For students of the undergraduate systems engineering program at Regent, unless they have already worked in the industry for at least a year or two (even if it was not related to systems engineering), their Career Maps would largely be empty! However, drawing their own Career Maps would force students to think about their entire careers as systems engineers, and to look beyond their first system engineering job immediately after graduation. Having drawn their Proficiency Profiles twice prior to graduation,

[5] A 'role' is a related set of systems engineering activities. See Chapter 3: Fifteen Roles Systems Engineers Play in Pyster et al 2018.

students are provided opportunities to visualize the systems engineering roles they played and the lifecycle phases they were exposed to during their summer internships, year-long capstone project, and other systems engineering activities in which they were involved. This would also enable them to consider how they would like their Proficiency Profiles to evolve over the next several years, enabling them to begin planning their systems engineering careers towards senior leadership positions, not just as a desire but as a goal that is achievable in time.

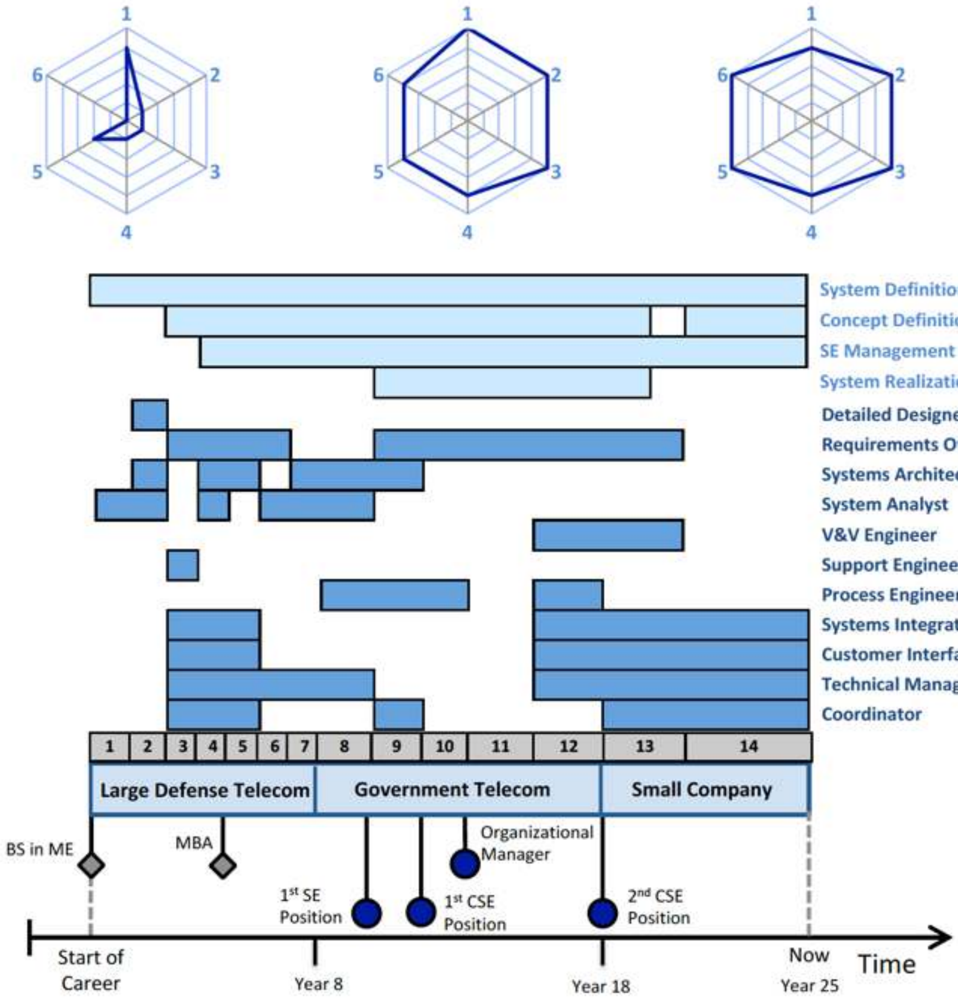

Figure 3. An Example Career Map

4. The Role of Mentoring in Systems Engineering Education

Helix identified three key forces that enable the increase of proficiency levels of systems engineers, in this order of importance:

1. Experiences
2. Mentoring
3. Education & Training

While these are easily relatable to working professionals in the industry, they take on a very different sense when viewed from the perspective of an undergraduate student who may have no industry experience at all. An undergraduate program in systems engineering falls under the third category, but it is also only the third most important force that helps in improving the effectiveness of systems engineers. During the undergraduate program, there are some opportunities to acquire systems engineering experiences including summer internships and capstone projects. Regent University's program would provide these opportunities as well, but the challenge is to recognize the value and need for mentoring and to explore ways to provide it in any meaningful way within the bounds of an undergraduate program.

First, the role of a faculty member, particularly during the capstone project, is to also serve as a mentor to the students. In addition to getting the students to work on their capstone projects, the faculty member would use the Proficiency Profiles of the students to understand their strengths and to identify areas that need improvement. Over the course of the year-long capstone project in the final year, students would benefit from one-on-one interactions and mentoring from the faculty member. Through that relationship, students are expected to develop skills and abilities that are difficult to obtain through typical coursework.

Secondly, it is proposed to form a pool of systems engineering professionals – senior or retired, who may be willing to serve as mentors to the undergraduate students of systems engineering. Their commitment would be limited so as not become a burden, but at least two substantial interactions between the mentor and mentee are envisioned, that would help transfer implicit systems engineering knowledge to the student and also motivate and excite the student into a systems engineering career. It is desired that a personal relationship will be established that would extend beyond graduation and well into the careers of the young systems engineers.

Summary and Conclusions

Without trying to be exact about the lines of separation, it can be observed that the previous generation(s) of systems engineers never really possessed a formal degree in systems engineering. They learned systems engineering at work, over time and with experience (that often involved scar-tissue). This is true for many who currently occupy systems engineering leadership positions at various organizations, including senior members of INCOSE. In the current generation of systems engineers, many seem to have a graduate degree in systems engineering; and increasingly, a professional certification in systems engineering (such as Associate Systems Engineering Professional (ASEP) or Certified Systems Engineering Professional (CSEP))[6] as well. In the next generation of systems engineers, it is likely that some formal education and / or certification would become necessary for any systems engineering position in industry, academia, or government.

Regent University is on a mission to generate effective systems engineering through its undergraduate systems engineering program, who would go on to becoming systems engineering experts and leaders around the world. The Helix project and its findings have helped shape the undergraduate program in ways that have not been done in formal systems engineering programs, especially at the undergraduate level.

Epilogue

The undergraduate program at Regent University has just been launched (in the fall of 2018), and it will be a few years before the first graduate of the program enters the systems engineering workforce. Further, the true impact of the Program will be fully appreciated only when the graduates actually go on to become leaders in systems engineering, many years after graduation. While it will certainly be

[6] ASEP (Associate Systems Engineering Professional) and CSEP (Certified Systems Engineering Professional) are professional certifications awarded by INCOSE

interesting to validate the efforts that have gone into designing the undergraduate programs at that time, continuous evaluation is expected to continuously improve and update the B.S. in Systems Engineering program at Regent.

List of Acronyms Used in this Paper

Acronym	Explanation
ABET	Accreditation Board for Engineering and Technology
ASEP	Associate Systems Engineering Professional
CSEP	Certified Systems Engineering Professional
DoD	US Department of Defense
INCOSE	International Council on Systems Engineering
SERC	Systems Engineering Research Center
STEM	Science, Technology, Engineering, and Mathematics

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About the Author

Dr. Devanandham (Deva) Henry holds an undergraduate degree in Aeronautical Engineering from the Madras Institute of Technology, India and a graduate degree in Aerospace Systems Engineering from the Indian Institute of Technology – Bombay, India. For almost a decade, he worked as a Scientist at the Aeronautical Development Agency, Ministry of Defense, Government of India and was involved with the design and development of the Air Force and Naval versions of the Indian combat aircraft, known as Tejas.

In 2006, Dr. Henry came to the Stevens Institute of Technology in the U.S. to pursue a Ph.D. in Systems Engineering. While at Stevens, he also served as a lecturer and a research engineer. He was actively involved in research projects sponsored by the U.S. Department of Defense at the Systems Engineering Research Center that produced the Guide to the Systems Engineering Body of Knowledge (SEBoK), the Graduate Reference Curriculum for Systems Engineering (GRCSE), and Atlas: The Theory of Effective Systems Engineers. In the summer of 2017, Dr. Henry joined Regent University as an Assistant Professor to develop a new undergraduate Systems Engineering program.

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3. ARTICLE

3.1 An Alternate View of the Systems Engineering "V" in a Model-Based Engineering Environment

by

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The iconic Systems Engineering "V" has served the aerospace and defense industry for over 25 years as a model of the product development process for complex systems. This familiar V model portrays the decomposition of requirements and design definition from the top-level system or system of systems down to components and the resulting system integration and validation from components up to the end-user system. The V model originated at a time when engineering processes required manual handoffs and interfaces between disciplines by exchange of documents. Today, exponential improvements in computing technology allow engineers to dramatically increase the use of analytical models and simulations leading to the creation of digital twins of the physical systems. The Systems Engineering V model does not adequately describe this growing Model-Based Engineering (MBE) environment. A new MBE Diamond model is proposed to replace the V model to address the creation of digital twins as well as use of twins to design and optimize systems before the first physical item is built. This MBE Diamond is an evolution of the V model and retains much of the systems engineering approach while recognizing changes that are affecting both our engineering process and product design as we move into a model-based engineering era.

I. Introduction

The world is currently undergoing a fourth industrial revolution (Fig. 1) where the confluence of mechanical, electrical and computing technologies are creating extraordinary opportunities due to the connectivity of systems and data. Industry 4.0 is having a major impact across all market sectors and across the globe, aerospace companies are embarking on enterprise digital transformation programs that address a future where cloud computing, data analytics, additive manufacturing, autonomous robots, augmented reality, and the industrial internet of things are woven together by data and information. Service companies are building digital twins of their physical products to provide clients with insights gleaned from extensive data analytics. Over the product lifecycle, increasing detail and fidelity will be added to virtual products, production systems, and product support ecosystems to enhance the quality, cost, performance and safety of their physical counterparts. But more importantly, the data will be connected through models and simulations to provide a single source of information that is authoritative, live, and consumable.

Furthermore, these same technologies are being deployed by company chief information officers as part of enterprise digital transformation initiatives to simplify, automate, and digitalize their internal operations.

Government agencies and military services have embarked on similar digital transformation efforts to improve their in-house capabilities as well as their connectivity to contractors and suppliers. The U. S. Department of Defense is leading an effort to implement Digital Engineering Transformation [1] across the military services. Within the DoD, the Air Force has been leading a Digital Thread / Digital Twin effort aimed at the entire product lifecycle, from concept to support, while the Navy recently issued a request for information to solicit industry inputs for a future systems engineering framework that leverages a model based environment. NASA, too, is planning their digital transformation to improve their operations and deliver increased mission capability to the nation.

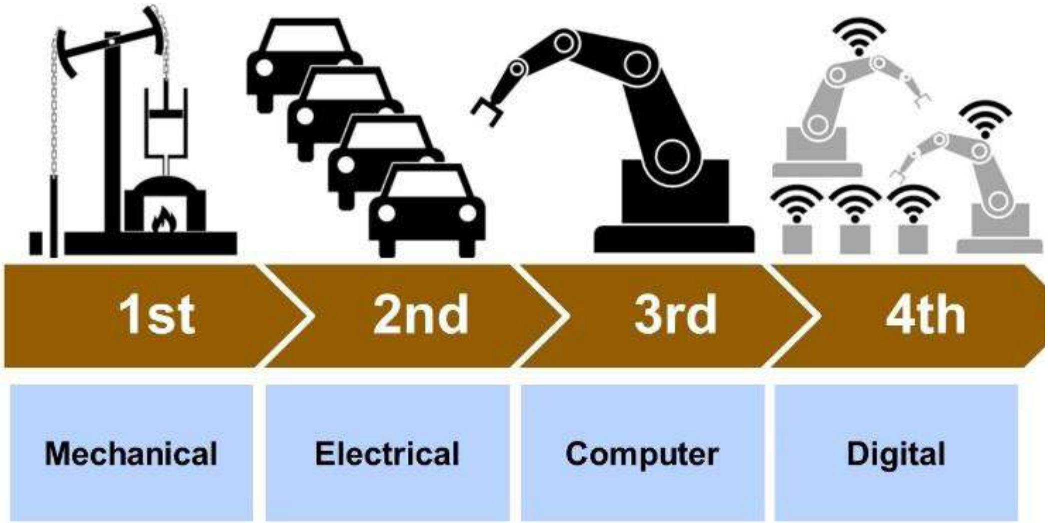

Figure 1: The Fourth Industrial Revolution (after AllAboutLean.com)

II. The Classic Systems Engineering Approach to Product Development

According to the INCOSE Systems Engineering Handbook [2], the Systems Engineering V was introduced in 1991 by Forsberg and Mooz. Since its introduction, the V model has been adopted industry-wide as an instructional framework for understanding the system development process. As shown in Fig. 2, the traditional V depicts a sequential development process from concept development through fielding. The model depicts top-down development activities on the left side, and corresponding bottoms-up integration, verification and validation activities on the right side. Some versions include horizontal connections between the development and validation efforts at each level of development.

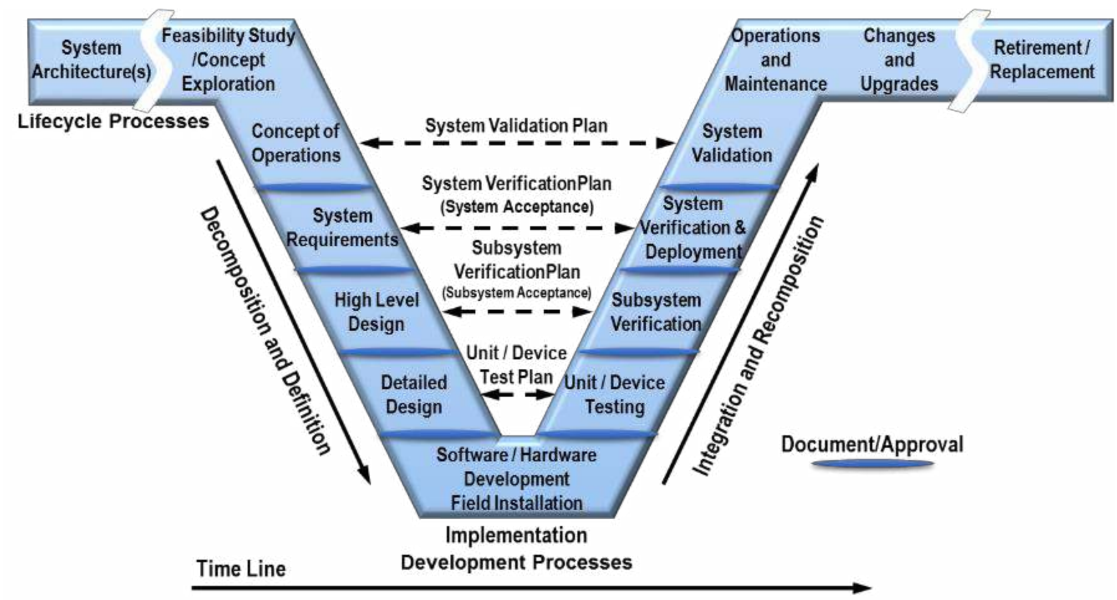

Figure 2: The Classic Systems Engineering V Model (U.S.DOT) [3]

The V model originated at a time when engineering processes had become narrowly stove piped and required manually intensive handoffs and interfaces between disciplines using document-centric exchanges. This, coupled with a gated program management approach, led to the codification of a linear sequence of design and validation activities to allow for a logical breakdown of program phases and organizational responsibilities.

The V model depicts a sequential development process that starts at the top left side of the V with concept development and requirements allocation. It proceeds through system architecture definition and into system design and development. This results in the realization of the physical system at the bottom of the V. Next, it progresses into system integration, test and evaluation, and finally transitions to operation and maintenance.

While it has been modified countless times across the industry to communicate or emphasize various needs, the basic tenets hold common across the lifecycle:

- Left side of the V depicts a progressive tops-down approach starting with high level conceptualization of the system and ends with detailed designs of all components that are ready for implementation.
- Bottom of the V reflects the implementation of the design reflecting the manufacturing or production of the system.
- Right side of the V shows the incremental bottoms-up integration, verification and validation along with fielding of the product or system. It can continue through operations, maintenance, support and eventual retirement.

The original V model was aligned to the program development process and therefore is frequently interpreted as a sequential process where tasks end and start with little to no feedback. This sequential view fails to depict the rapid interplay and growing concurrency between the design and verification activities. Increasingly capable modeling and simulation tools can verify and validate designs in a virtual manner before actual testing takes place. Lean agile methods also shorten the time between minimally viable solutions and incremental improvements. Attempts to address this have resulted in updated versions of the V model containing horizontal feedback lines to “close” the V.

Increasing competition in the marketplace drives companies to develop optimal product solutions. Hence the need to develop digital twins that capture the product in its intended environment – whether that is the assembly of the product in a factory, the system operating in the battlefield, or the sustainment of the system by the logistics network. The creation of these digital twins is necessary to create the entire digital thread across the product lifecycle. This ensures data continuity from as-designed, to as-built, to as-operated, to as-maintained condition.

A further shortcoming of the V model is that is often interpreted as a product-centric development process that doesn’t easily translate to software, networks, production systems, or services. Today, new markets and business models are leading to a growing sector of Industry 4.0 goods and services that aren’t manufactured in traditional factories. With the emphasis on simulations as deliverables, data provided as a service, and cyber-physical systems as both equipment and products, there is a need to define model based engineering processes for virtual systems. The classic V model must be modified to adequately address this emerging pathway.

The question of whether the System Engineering V is still relevant has been previously raised by the authors. This paper contains feedback from a number of individuals and organizations and presents an alternate “MBE Diamond” that addresses the co-development of digital twins as an integral part of today’s systems engineering methodology.

III. Transforming Systems Engineering for the Digital Age

Since the dawn of the Jet Age, the complexity of aerospace and defense (A&D) systems has grown exponentially. INCOSE illustrates this with an expanding set of attributes that grow beyond the cyber-physical to include ecosystem and system of systems (Figure 3).

Unfortunately, this increased complexity has resulted in significantly increased development time and costs for A&D products. DARPA studies show the escalation of development time as aerospace system complexity increases. Other industries, like automotive and the semiconductor field show the opposite trend, suggesting that their development costs have decreased or stayed level over time. The A&D industry invented much of the underlying computing technology and software applications that enable complex scientific and engineering endeavors. Why hasn't the use of such advanced technology resulted in airplane cost trends that are similar to cars and chips?

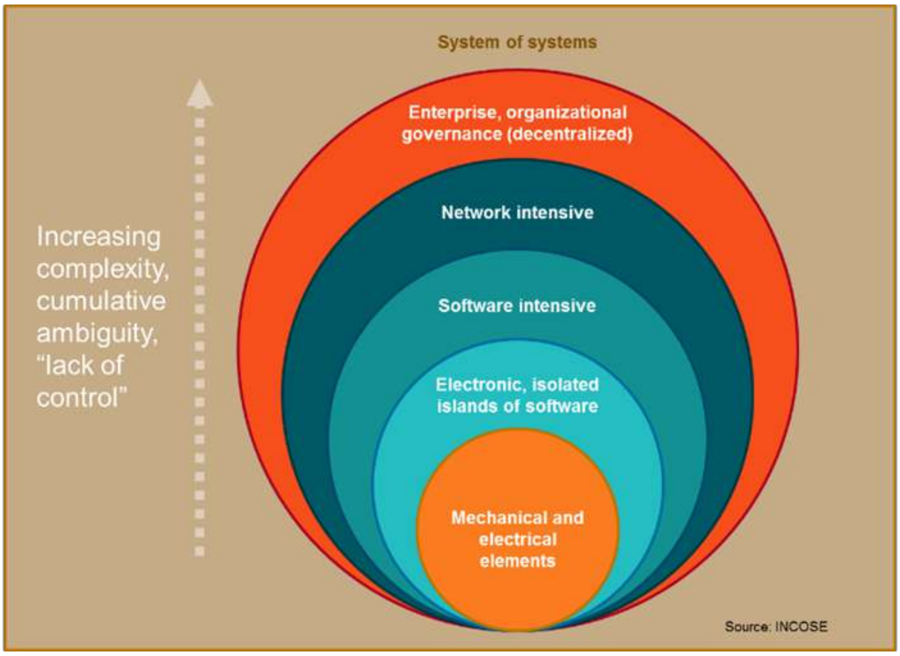

Figure 3: Increasing Systems Complexity (after INCOSE) [4]

Today, the application of systems engineering to A&D systems is more important than ever. Products, systems and services must be developed affordably by engineering teams that can deliver high levels of productivity and first time quality. But, the products, and the way to develop them, have been dramatically impacted by Industry 4.0, digitalization and model based engineering. Model based engineering is being implemented to enable agility, feedback, and iterative development in contrast to a one-way, sequential, waterfall process.

Collectively, government and industry have yet to capitalize on the promise of digital engineering. With the introduction of carbon fiber reinforced composites in the 1960s, early engineering efforts were only able to eke out marginal improvements in cost and performance. It wasn't until advances in material chemistry, manufacturing automation, and certification methods enabled composites to be designed for significant cost, performance and cycle time benefits. Today, our use of digital technologies is undergoing a similar evolution, albeit at a much faster pace. Conversion of documents and drawings into digital form provides only limited benefit. Once digitization is complete and an authoritative, single source of data is established, then a transformation to model based definition, simulations and digital twins can occur (Fig. 4).

The concept of a digital twin, while easy to describe, is difficult to realize. Physics-based computational models are often incorrectly equated to digital twins. The product digital twin addresses both product optimization and operational feedback. It is a control model vs a computational model. The twin simulates the real-time behavior of the system and its operational environment as adjusted by sensor data.

Traditional engineering analysis focused on accurate assessments of the state or static condition of a system. Multiple states, when combined, reduced the uncertainty and risk of operating a system throughout a mission and over an entire lifecycle. Current technology enables the simulation of system behavior of simplified systems – but the drive is to increase fidelity and complexity to capture real life behavior of both the system and the operational environment.

In short, digital twins of the factory, the battlefield and the supply and logistics system are needed to accurately predict behavior during development, operations, and sustainment.

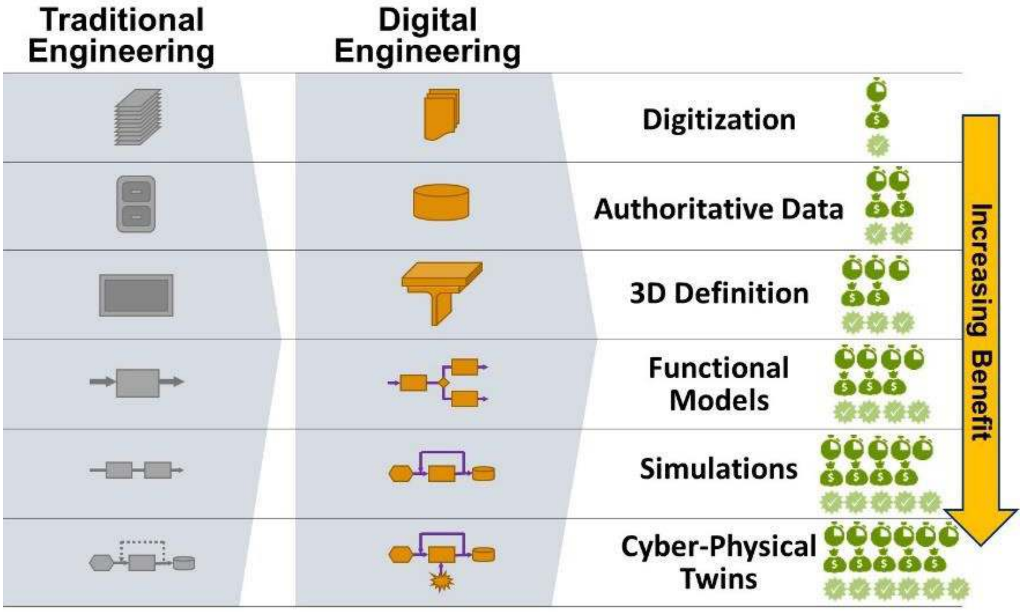

Figure 4: Digital Engineering Enables Transformational Change

Furthermore, as new capabilities are introduced into the model-based engineering (MBE) process, the digital thread can extend across customers, OEMs, and suppliers, providing an unprecedented level of concurrency, collaboration, and feedback throughout the ecosystem.

Cyber-physical systems, however, are not just mirror images of physical vs virtual. They are evolving into singular entities that are two sides of the same coin. Industrial companies, for example, have manufacturing plants connected by the Industrial Internet of Things (IIoT): every machine, device, robot, computer, and sensor is connected to the network and is controllable, controlled, and either producing or harvesting data. This data is fed into the virtual simulation of the entire assembly line – the digital twin of the production system so that the model can be compared against the actual production parameters in real time. The digital twin in essence is the both the representation of the physical system and the intelligence for controlling and/or modifying the production line.

IV. Alternatives to the System Engineering V Model

The origin of the now iconic System Engineering V was in the 1990s, some 30-40 years after the recognition of the need for systems engineering to develop complex ballistic missile systems. Model-based engineering, and the greater model-based enterprise continues to evolve as technologies improve and organizations adapt their business processes. Looking forward, key tenets of an MBE environment include:

- Multi-dimensional, iterative process that evolves the system from requirements, through models, to the physical implementation.
- Reflects the integrated nature of each element in the life cycle, linked with inherent feedback to related elements.
- Ensures lifecycle relationships that span the ecosystem in terms of product definition, production system characterization, end user operations, and aftermarket services and support.
- Allows global collaboration and visualization among a distributed set of stakeholders.
- Creation of virtual models (digital twins) for development of physical systems as well as operation of cyber-physical systems.

To better reflect the increased complexity of model-based engineering, a new depiction that acknowledges the all-ways feedback enabled by MBE is presented in Fig. 5. This MBE Diamond reflects both classical systems engineering (the lower V) of a physical system and increased focus on the creation and use of digital twins (the mirror reflection of the V forming a diamond shape) that is multi-dimensional, integrated and iterative across multiple product domains.

The classic V is foundational to transform needs into solutions and remains a cornerstone of the MBE Diamond (the lower V). The baseline system design develops and matures over time and results in a physical system that is ultimately delivered as a product or service. The progress from a concept "as-needed" to "as-planned" is "down the V" as the maturity of the design advances toward manufacturing. The bottom of the V represents the physical construction, "as-built" which progress through test, certification, deployment, operations and sustainment "as- supported." The design at any stage addresses its lifecycle counterpart and is informed by the operational solution (or anticipated version).

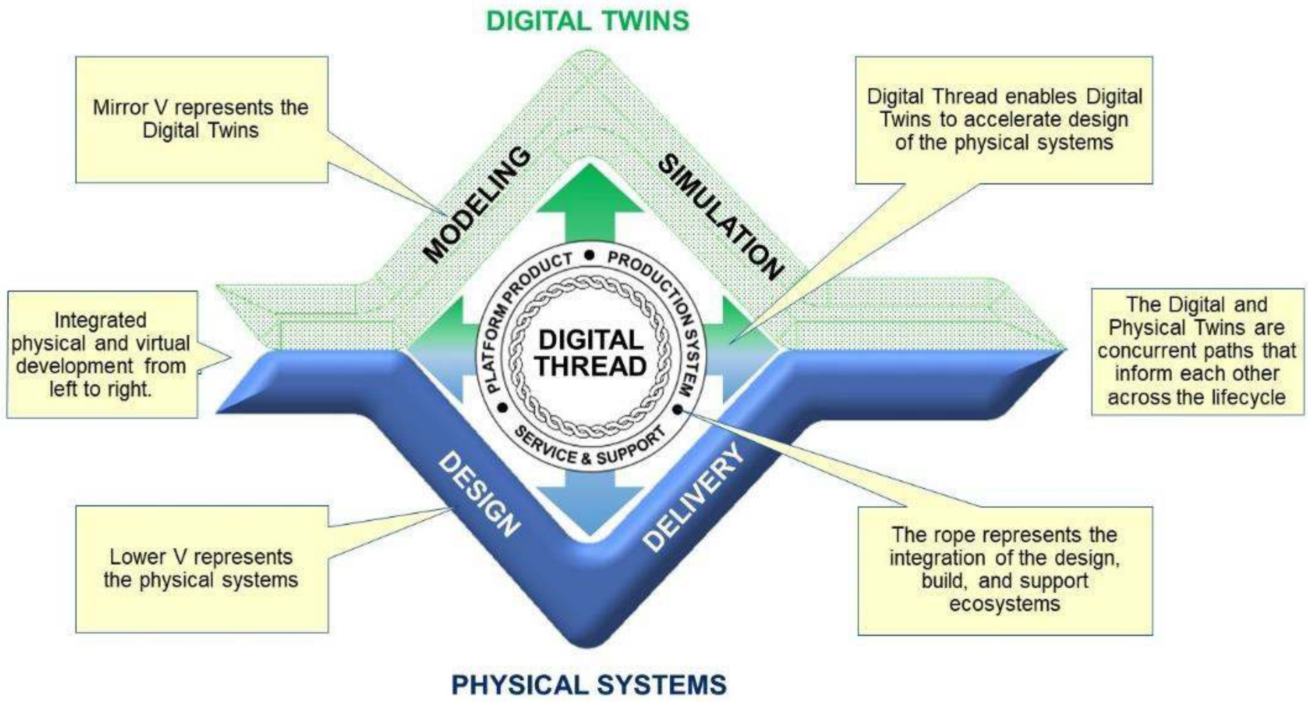

Figure 5: MBE Diamond - A New Symbol for a New Engineering Paradigm

Today, considering Industry 4.0 cyber-physical systems and digitalization, we must add the digital twins as a separate, but integrated engineering pathway. The mirror image of the physical system V becomes an inverted V that represents the design and realization of the behavioral simulations. The definition of the digital twin progresses through a similar sequence of events – system of system models to models of how parts are manufactured or software is productionized. Likewise, the solution is realized through increasing levels of sophistication of simulations – the factory, the parts, the system, and the ecosystem. The digital twin pathway, however, is not an entirely separate activity. The steps of model design and development correlate exactly to the progression of the physical baseline. For example, the SoS model is used to define the as-needed configuration and the System model is used to define the as-offered configuration.

In essence, the models inform the design of the configuration. As models turn into behavior simulations, the same relationship occurs between virtual and physical. The simulations can inform and also be informed by the physical system. The simulation of the factory (virtual production system) can be used as real time control of the factory to create the as-built physical configuration. Virtual qualification can simulate the actual test conditions and relate to and in some cases replace physical testing. The virtual informs the physical, and as IoT devices are used, the physical informs the virtual. The interplay is simultaneous along the lifecycle and between the physical and digital twins.

V. Conclusion

System Engineering must leverage all aspects of model based engineering and therefore the MBE Diamond is proposed as an enhancement or replacement for the Systems Engineering classic V model. Changing the iconic symbol highlights the evolution of Systems Engineering and it is an important step in defining the changes in the digital engineering process and teaching it to the next generation of engineers.

Acknowledgments

The authors wish to acknowledge feedback and ideas from a number of people and organizations since the Systems Engineering V model options were first presented at the 2018 National Institute of Standards and Technology Model Based Enterprise Summit. The following Boeing employees provided notable expertise and guidance: Christi Gau Pagnanelli, Brian Nielsen, Jay Ganguli, Brian Chiesi, Jeff Plant, Michael Hogan, Steve Walls, Kristen Bengtson, Robert Maloe, Alex Chao, Len Quadracci, Jeff Stein, Kelly Graeber, and Rob Saunderson. Organizational feedback and discussions were held with Air Force Research Laboratory, Air Force Institute of Technology, Air Force Lifecycle Management Center, Dassault Systèmes, Department of Defense, National Institute of Standards Office of Naval Research, Perduco Group, Rolls-Royce, Siemens PLM, and UCLA.

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ARTICLE

3.2 Integrating Program Management and Systems Engineering

by

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Hi

Many of you are familiar with the alliance between the International Council on Systems Engineering (INCOSE) and the Project Management Institute (PMI) thanks to my colleague Ralph Young's excellent series of articles. He and I both believe the harmonious interaction of these two domains is critical, not only to individual projects and programs, but even to the fabric of society.

I'm currently the Point of Contact representing INCOSE on the alliance, and we are fortunate to have Stephen Townsend as the representative from PMI. Together we work to connect the two organizations and support the message of integration between them.

Here's a little background on the alliance:

In2010, John Thomas, INCOSE President Elect, met with leaders at the Project Management Institute. John's observation of life at Booz-Allen was that the U.S. government market was increasingly asking for systems engineering services *or* program management services, but very rarely were they asking for *both*. He shared with PMI management that the two organizations must somehow be doing a disservice, since clients felt the need for one or the other rather than understanding that the real goal has always been an integrated PM-SE *team*.

A Strategic Alliance Agreement between INCOSE and PMI was signed on 15th Feb 2011 by the respective Presidents, Samantha Brown and Mark Langley. A joint INCOSE-PMI white paper was published in September 2011 entitled “Toward a New Mindset : Bridging the Gap between Program Management and Systems Engineering” by Mark Langley, PMI President and Chief Executive, Samantha Robitaille-Brown, INCOSE President and John Thomas, INCOSE President Elect in both INSIGHT and PM Network.

Research on PM-SE integration was performed for the alliance by MIT, and two very successful publications emerged. The *Guide to Lean Enablers for Managing Engineering Programs* brought work from the INCOSE Lean Working Group to market and went on to win the prestigious 2013 Shingo Prize for Operational Excellence. The 2017 book *Integrating PM and SE* is in the second printing. Thanks to the marketing horsepower of the PMI, well over 100,000 PMs and SEs worldwide have been exposed to the integration message.

In 2017, INCOSE officially chartered the PM-SE Working Group, giving a recognized home to the general pursuit of PM and SE integration effort. This action freed the alliance from carrying both an INCOSE - PMI organizational relationship responsibility and one of representing all SE and all PM interested in better integration regardless of societal allegiance. Today, each has a discrete channel and can work more effectively towards meeting INCOSE's Vision 2025 goals.

Here's what we are doing right now:

INCOSE and PMI are in the process of renewing the alliance agreement, so Stephen, myself and others will meet during the INCOSE International Workshop (IW) in Torrance California to review and converge on final language.

We will retain reciprocal attendance at each other's events and the general framework of interaction; the only significant change will be a sharp focus towards communicating the message rather than our previous mission of capturing and publishing research. There is always more to study, but we now have compelling evidence of the profound inefficiency created by poor PM and SE integration, along with a sound recipe for preventing / correcting the problem.

During 2019, the emphasis will be on reaching key decision makers - those who set policy and others with the ability drive changes in behavior across large groups rather than simply individuals. In the United States, the 2016 Program Management Improvement Accountability Act, or PMIAA, offers just such an opportunity.

The PMIAA creates an incentive for the US Federal agency training community to seek not just healthy PM and SE, but to drive towards the greater objective of the two domains working in conjunction rather than in conflict. This is a key strategic interest area for PMI, and one that INCOSE can easily follow to potentially great impact.

I look forward to sharing progress from our meeting in the next edition of SyEN, until then please feel free to send me any questions or comments you may have.

4. SYSTEMS ENGINEERING NEWS

4.1 The Past and Future of Systems Engineering

Justin McMurray, Northrop Grumman Flight System Solutions Business Unit Director, provided a presentation at the INCOSE Western States Conference in September 2018. He indicated that our future will be increasingly interconnected, and software driven, that systems will be increasingly automated with machine learning, virtual based with rapid prototyping, utilizing multi-disciplinary design analysis and optimization driven design, involving open architecture and modularity.

View the Presentation here (INCOSE Connect login required)

Listen to the Presentation here (INCOSE Connect login required)

4.2 29th Annual INCOSE International Symposium

July 20-25th 2019

Image Source

The annual INCOSE International Symposium is set to take plane in Orland Florida from 20-25th. At the 2019 conference, participants can expect to:

- Engage with colleagues from the Systems Engineering community
- Learn about the state-of-the art methods and essential skills for Systems Engineers
- Find out how people are making a difference with Systems Engineering

Key dates

Notification of Acceptance - 15th February 2019

Paperless Presentation Acceptance - 15th March 2019

Final Paper, Panel, Tutorial Submission - 15th March 2019

Learn more about the event and submission guidelines

4.3 INCOSE Foundation Donation

Letter from John Snoderly and Holly Witte

Chair and Action CEO of the INCOSE Foundation, John Snoderly and Holly Witte, Managing Director of the INCOSE Foundation distributed a letter thanking all contributors to the INCOSE Foundation in 2017 and 2018 for their generous donations. Snoderly acknowledges that donations have enabled the Foundation to award awarded Grants and Scholarships in partnership with Johns Hopkins University, Stevens Institute, the James E. Long Fellowship, the David Wright Award, the Chesapeake Chapter and the ISEF (International Science and Engineering Fair). The 2017 and 2018 round of grants contributed to substantial progress in the following endeavors:

- **INCOSE SA Greatest Young Systems Engineer of the Year Challenge**
- **INCOSE Crossroads Chapter STEM program in Indianapolis inner city schools**
- **INCOSE Power and Energy Working Group - The evolution of a system model**
- **INCOSE Systems Science Working Group and Natural Systems and Complex Systems Working Group - An Open Source Relational Data Base (RDB) on Systems Processes Theory & Systems Pathology: How Systems Work and Don't Work**
- **INCOSE SS WG and NSCS WG - Initiation of a New Professional Society -International Society for Systems Pathology (ISSP)**
- **INCOSE Polish Chapter** - Promotion of the systems engineering approach in Poland
- **JACK RING - Starshine Academy beta test of the SySTEM Educator Initialization material and method**
- **INCOSE UK Chapter** - Systems Engineering Architecture to define and develop a model of INCOSE
- **INCOSE TEXAS GULF COAST CHAPTER** - Software Traceable API Standards

John and Holly affirm that the most impressive characteristics of grant proposals following review was the: the breadth of the work and different geographic areas represented. The Foundation accepts any size donation and welcomes donations online or through mail to address:

INCOSE Foundation

7670 Opportunity Rd., Ste 220

San Diego, CA 92111 USA

foundation@incose.org

or phone 1 800 366 1164

Gifts are fully tax-deductible to the extent allowed by the laws of each country. This link may provide useful information as you determine tax code in your country: http://www.cof.org/resources/global-grantmaking

4.4 The Systems Engineering Society of Australia has its Own YouTube Channel

SESA's YouTube channel can be found via the following link here. You can also subscribe to the channel to receive regular updates about content.

4.5 INCOSE and SAE International Announce MOU

by

Christine Kowalski (Nov 09, 2018)

The International Council on Systems Engineering (INCOSE), the largest organization in the world dedicated to systems engineering, has signed a Memorandum Of Understanding (MOU) with SAE International, a nonprofit and knowledge source for the engineering profession, to jointly collaborate and participate within the global engineering community.

The MOU between INCOSE and SAE International formalizes the partnership between the two organizations to work on common projects and challenges, including the development and promotion of best practices and guidance, along with training and materials that can support projects and organizations in the field of systems engineering throughout the world.

According to INCOSE President Garry Roedler, INCOSE and SAE International have a mutual commitment to improving the state of systems engineering practices.

"Collaborating will help us achieve our shared goals, and bring the systems engineering community closer together as we continue to promote this important work," said Roedler.

The scope of the partnership will focus on collaboration via joint event promotion, working groups, product development and webinars, as well as professional development via tutorials, videos and more. INCOSE will also include a representative from SAE on the core team of its Future of Systems Engineering (FuSE) Initiative, a forward thinking, multi-organization program.

"By joining efforts, INCOSE and SAE will facilitate the exchange and development of knowledge and best practices, with an eye on comprehensive integration into the production, operation and support of successful engineering systems," said Frank Menchaca, Chief Product Officer, SAE International. "We look forward to collaborating closely in the years to come, with a focus on advancing the field of systems engineering – which plays a vital role in the evolution of global technology and innovation."

About the International Council on Systems Engineering

The International Council on Systems Engineering (INCOSE) is a not-for-profit membership organization that promotes international collaboration in systems engineering practice, education and research. INCOSE's mission is to "address complex societal and technical challenges by enabling, promoting and advancing systems engineering and systems approaches." Founded in 1990, INCOSE has more than 70 chapters and over 16,500 members worldwide. For additional information about INCOSE, call 1-858-541-1752 or visit www.incose.org. Become a member today.

About SAE International

SAE International is a global association committed to being the ultimate knowledge source for the engineering profession. By uniting over 127,000 engineers and technical experts, the organization drives knowledge and expertise across a broad spectrum of industries – encouraging a lifetime of learning for mobility engineering professionals and setting the standards for industry engineering. For more information, visit www.sae.org.

4.6 INCOSE Membership Fees 2020

by

Garry Roedler

Effective 1 January 2020, INCOSE membership fees will increase in all individual membership categories as shown below for maintenance of quality of programs, initiatives, investments, working groups, seminars, training, and influence.

Membership Type	2019 Fees (PPP Band 1)	Approved Fees 1 Jan 2020 (PPP Band 1)	Note
Regular - 1 year	$145	$160	$160 per year
Regular - 3 year	$405	$445	$148.33 per year
Regular - 5 year	$625	$690	$138 per year
Student	$38	$50	
Senior - 1 year	$80	$90	$90 per year
Senior - 3 year	$225	$250	$83.33 per year
Senior - 5 year	$360	$395	$79 per year

For Individual Regular and Senior members, discounts will be applied for 3-year and 5-year advance payment of dues. See the membership price list at the following link for the specific pricing. https://www.incose.org/docs/default-source/policiesbylaws/price-list.pdf

As a new part of the membership fee structure, INCOSE is adding two stepwise transitions, as follows:

- Transition from Student Member to Individual Regular Member - students will have two interim years at 65% of the Individual Regular membership fee. This will give the students an opportunity to adjust to their new financial responsibilities and enable them to remain engaged members in INCOSE during that transition.

- Transition from Associate Member to Individual Regular Member - the transition to Individual Regular members will also include two interim years at 65% of the full Individual Regular membership fee. Once the transition to Individual Regular Membership is complete, the Associate Membership is released and available for reallocation within the CAB organization.

Finally, as indicated in the memo sent out in March 2018, we introduced a Purchasing Power Parity (PPP) [1] based membership fee model for INCOSE Individual Regular members for certain countries. That memo and the Membership Price List at the link above provide the details for the membership fee transition. INCOSE Policy MBR-100 covers this topic.

January 2018 Memo

Note: Memorandum Of Understanding (MOU) countries do charge membership fees in local currencies and may charge an additional fee on top of the published fees to cover the cost of additional services, activities, currency risk, etc.

The Board of Directors recognizes that any increase in dues may cause some hardship for their members, but the Board of Directors also acknowledges the fiduciary responsibility to INCOSE members to structure a sustainable financial model as INCOSE grows and matures. In the past year, INCOSE has established the foundation of new value streams that will provide additional sources of revenue for the organization and help reduce the dependency on membership fees as the primary income source. At the same time, these value streams will concurrently provide more products and services for our members, building the value provided by INCOSE.

Note: The Corporate Advisory Board membership fees are not impacted by this change. They are maintained on a different cycle.

The INCOSE Board of Directors is dedicated to moving forward with the INCOSE mission and vision, influencing the evolution of Systems Engineering and helping provide resources for professional development and performance.

4.7 International Institute of Business Analysis (IIBA) Introduces New Agile Extension to BABOK Guide

The International Institute of Business Analysis has introduced an Agile Extension Version 2 to the Business Analysis Body of Knowledge. The Agile Extension to the BABOK® Guide describes both the mindset and practices to help users use continuous feedback and quick learning to prioritize delivery, minimize waste, create better business outcomes and increase value delivered.

Based on experiential learning, the Agile Extension introduces a rolling planning model with three planning horizons – strategy, initiative and delivery – to help users adapt quickly to changing customer needs and ensure value is always added.

Version 2 incorporates the Business Analysis Core Concept Model™ and new and updated techniques, including Feature Driven Development, Impact Mapping, Value Modelling and Visioning.

Developed in collaboration with the Agile Alliance, the Agile Extension to the BABOK® Guide provides guidance for agile practitioners, or anyone interested in leveraging effective agile business analysis to create better business outcomes that add real business and customer value.

More Information

5. FEATURED ORGANIZATIONS

5.1 Society of Asian Scientists and Engineers (SASE)

SASE is dedicated to the advancement of Asian heritage scientists and engineers in education and employment so that they can achieve their full career potential. In addition to professional development, **SASE** also encourages members to contribute to the enhancement of the communities in which they live. **SASE**'s mission is 1) to Prepare Asian heritage scientists and engineers for success in the global business world; 2) Celebrate diversity on campuses and in the workplace; and 3) Provide opportunities for members to make contributions to their local communities. The Procter & Gamble Company saw the opportunity to improve the recruiting, retention, and development of Asian heritage scientists and engineers via a nationally-recognized technical organization with student chapters on college campuses. In 2007-08, P&G provided the initial membership contribution to establish SASE as a 501(c)3 organization. SASE is the official magazine of the Society. The fall conference issue is distributed to all conference attendees and all chapters. Participation in the conference issue of SASE is included as a benefit of all conference sponsorships. SASE membership is open to men and women of all ethnic backgrounds.

More Information

5.2 National Initiative for Cybersecurity Education

NICE
NATIONAL INITIATIVE FOR
CYBERSECURITY EDUCATION

Image Source

The National Initiative for Cybersecurity Education (NICE), led by the National Institute of Standards and Technology (NIST) in the U.S. Department of Commerce, is a partnership between government, academia, and the private sector focused on cybersecurity education, training, and workforce development. Located in the Information Technology Laboratory at NIST, the NICE Program Office operates under the Applied Cybersecurity Division, positioning the program to support the country's ability to address current and future cybersecurity challenges through standards and best practices.

The mission of NICE is to energize and promote a robust network and an ecosystem of cybersecurity education, training, and workforce development. NICE fulfills this mission by coordinating with government, academic, and industry partners to build on existing successful programs, facilitate change and innovation, and bring leadership and vision to increase the number of skilled cybersecurity professionals helping to keep our Nation secure.

Get more of an overview of NICE through the NICE Brochure

More Information

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6. NEWS ON SOFTWARE TOOLS SUPPORTING SYSTEMS ENGINEERING

6.1 Agile MBSE for Industry 4.0 with OPM ISO 19450 using OPCloud

INCOSE Webinar 119

You may remember the article from SyEN 61 introducing Object Process Methodology (OPM). In this webinar, Dov Dori makes a case for OPM as an ideal tool to deal with the unique modeling requirements of Industry 4.0 or, the 4th industrial revolution.

Dov references Prof Dr-Ing Dieter Wegener, Siemens AG, Digital Factory “Industry 4.0” Coordinator as having said that Industry 4.0 would create a seamless link between the virtual world and the physical objects within the real world. Dov, therefore, argues that we must use a language and a methodology that cater for modeling and architecting systems with the Industry 4.0 hardware-software fusion paradigm mindset.

OPM with its bi-modal visual and textual presentation lends itself beautifully to that and further provides for complexity management through the built-in refinement-abstraction mechanisms.

OPM is now also supported by a cloud-based modeling tool called OPCloud.

If you want more detail, download this webinar from the INCOSE Connect archive.

Alwyn Smit

Principal Consultant & Course Presenter

Project Performance International (PPI)

asmit@ppi-int.com

7. SYSTEMS ENGINEERING PUBLICATIONS

7.1 Presentations for the Knowledge Professions

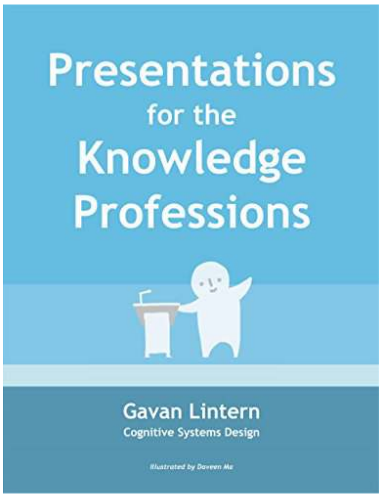

Image Source

by

Gavan Lintern

From the Amazon Webpage:

Are you a knowledge professional who is more concerned with informing and explaining than with persuading and motivating? Are you struggling with your presentations? Do you want to take them to another level?

There are many presentation books for business and marketing. This book, Presentations for the Knowledge Professions, fills a niche for those who work in a knowledge-intensive profession where ideas derived from research and design dominate. Most books on presentations imply that presenting is all about style but, in the knowledge professions, substance is crucial. A high-quality knowledge presentation will offer the substance of solid ideas within the style of an engaging format.

This book is for early-career knowledge workers such as scientists, researchers, engineers and medical practitioners. The author explains how to plan and deliver an engaging and informative presentation. He describes what works and, along the way, topples some pervasive myths that will have you heading in the wrong direction. If you are chronically dissatisfied with your presentations, and especially if you are frustrated that nothing you try makes you any better, the lessons in this book will help you move ahead. If you follow the planning and delivery structure outlined here, you will soon find that you are more comfortable and more satisfied with your presentations and you may even find that you are enjoying your time in front of an audience.

Gavan Lintern is an experienced presenter with over 100 conference presentations and 20 multi-day workshops to his credit. As Head of Human Factors, Defense Science and Technology Organization, Melbourne Australia, as Senior Scientist at Aptima, Inc in Boston, Massachusetts USA, and as Chief Scientist at General Dynamics-Advanced Information Systems, Dayton Ohio, USA, Gavan has been responsible for helping staff develop and deliver quality knowledge presentations. Although an accomplished speaker himself, he found it necessary, in his role as staff facilitator, to create and refine strategies for helping those who are inexperienced and lacking in confidence. He used that wealth of experience to develop his book on knowledge presentations.

Note: The Kindle edition of this book contains links to external resources that can be accessed only while it is being read on a device that is connected to the internet. It is not, however, essential to have continuous access to the online resources while reading this book.

Format: Hardcover

Publisher: Cognitive Systems Design (March 27, 2017)

ASIN: B06XWHRWBC

More Information

7.2 Systems Engineering for Astronomical Telescopes

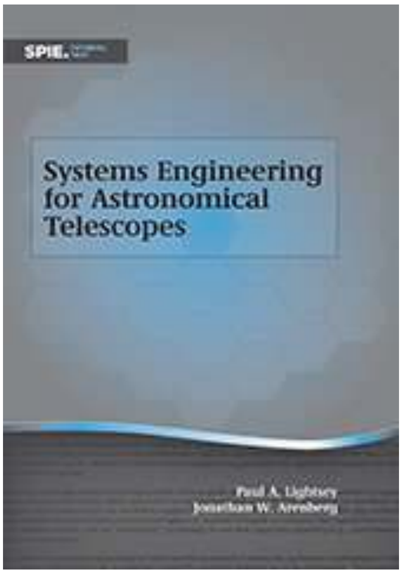

Image Source

by

Paul A. A. Lightsey

and

Jonathan W. Arenberg

From the Preface:

The discipline of systems engineering has been emerging since the 1940s. With the development of large ground-based telescopes, such as the Keck, Gemini, and the Very Large Telescope, and space telescopes, such as the Hubble Space Telescope, Chandra X-ray Observatory, and the Spitzer Infrared Telescope, the role of systems engineering for astronomical telescopes has come to the forefront. As we move forward into the next decade, there are numerous opportunities and the books provide an overview of systems engineering as it applies to large astronomical telescopes, with an emphasis on space telescopes, and the tools for supporting the development and management of future programs. Examples from previous programs are used to illustrate the concepts and processes. The important personality and behavioral aspects of good systems engineers are mentioned. The book is intended for aspiring new systems engineers and as a refresher or reference for current practitioners. It is also useful for engineers in other disciplines to better understand and guide their participation in the larger system endeavor. To paraphrase an old bumper sticker from years ago: Think systems, act discipline.

The stimulus to develop this book has evolved over time. The initial impetus for Paul Lightsey was a suggestion from Phil Stahl following a briefing of the results of the pre-Phase-A architecture study for the Next-Generation Space Telescope (which later became the James Webb Space Telescope, or JWST). Stahl suggested that Lightsey offer a short course on systems engineering and architecture development for SPIE. The seed was planted but took time to germinate. In the interim, Lightsey was an adjunct lecturer for the Johns Hopkins Masters in Space Systems Engineering program offered at Ball Aerospace, and also developed and taught an internal training course at Ball on architectural concept development. A few years later, Stahl invited Jonathan Arenberg and Lightsey to collaborate on status updates on the progress of the JWST program at a Mirror Technologies Meeting. A few years later, Arenberg was invited to develop a short course on systems engineering for SPIE. He agreed on the condition that he and Lightsey could co-develop the course. The course relied on the combined experience of the authors having worked on the Great Observatories Hubble Space Telescope, ChandraX-ray Observatory, and the Spitzer Infrared Telescope Facility, along with diverse experience from a multitude of other aerospace programs. The course was first presented at the SPIE International Conference on Astronomical Telescopes and Instruments at Montreal in 2014. At that time, the authors were invited to develop a text based on the course. The progress was slow, with a preliminary draft ready at the time of the SPIE International Conference on Astronomical Telescopes and Instruments at Edinburgh in 2016. The SPIE editors solicited reviews, which have been used to update the book, from colleagues and feedback from the short-course students. As we approach the imminent launch of the JWST and the reports from the studies for missions to be presented for the 2020 Decadal survey, the authors offer this book and hope that readers find it useful.

Publisher: The International Society for optics and Photonics (5 April 2018)

Pages: 164

ISBN: 9781510616547

More Information

7.3 Display and Interface Design: Subtle Science, Exact Art

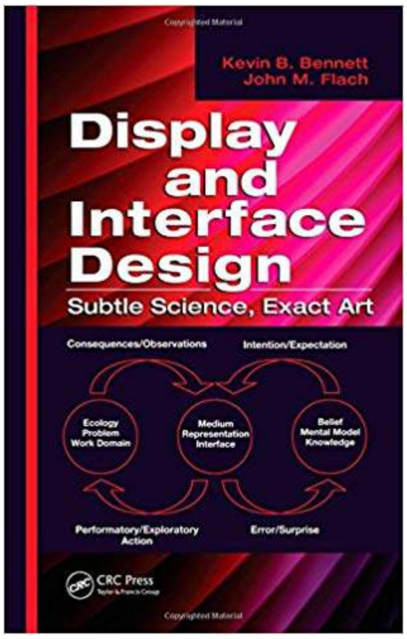

Image Source

by

Kevin B. Bennett

and

John M. Flach

From the Amazon Website:

Technological advances in hardware and software provide powerful tools with the potential to design interfaces that are powerful and easy to use. Yet, the frustrations and convoluted "work-arounds" often encountered make it clear that there is substantial room for improvement. Drawn from more than 60 years of combined experience studying, implementing, and teaching about performance in human-technology systems, **Display and Interface Design: Subtle Science, Exact Art** provides a theoretically-based yet practical guide for ecological display and interface design.

Written from the perspective of cognitive systems engineering and ecological interface design, the book delineates how to design interfaces tailored to specific work demands, leverage the powerful perception-action skills of the human, and use powerful interface technologies wisely. This triadic approach (domain, human, interface) to display and interface design stands in sharp contrast to traditional dyadic (human, interface) approaches. The authors describe general principles and specific strategies at length and include concrete examples and extensive design tutorials that illustrate quite clearly how these principles and strategies can be applied. The coverage spans the entire continuum of interfaces that might need to be developed in today's work places.

The reason that good interfaces are few and far between is really quite simple: they are extremely difficult to design and build properly. While there are many books available that address display design, most of them focus on aesthetic principles but lack scientific rigor, or are descriptive but not prescriptive. Whether you are exploring the principles of interface design or designing and implementing interfaces, this book elucidates an overarching framework for design that can be applied to the broad spectrum of existing domains.

Format: Kindle, Hardcover

Publisher: CRC Press; 1 edition (March 9, 2011)

ISBN-13: 978-1420064384

ISBN-10: 9781420064384

More Information

7.4 Technology Business Management: The Four Value Conversations CIOs Must Have With Their Businesses

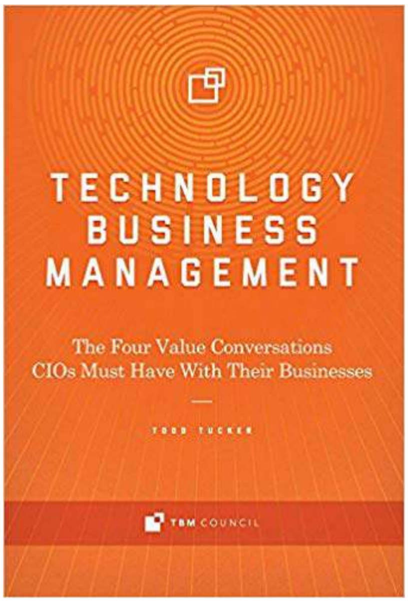

Image Source

by

Todd Tucker

From the Amazon Website:

For many CIOs, the value they deliver is elusive. It’s not that they do not create positive business outcomes, it’s that they have a hard time demonstrating value for the money spent. As a result, many IT leaders find themselves trapped in a vicious cycle of defending their budgets, cutting resources when times are tight, and struggling to keep pace with an insatiable business appetite for innovation. Meanwhile, business leaders increasingly rely on the cloud and other third parties for their technology needs, finding clear tradeoffs between cost, features, risk, and speed of delivery at their fingertips. CIOs must not only compete with these alternatives, they must embrace the new reality of a multi-sourced, service-oriented world. Many IT leaders are taking a more proactive approach to optimizing value. By using shared facts about cost, consumption, quality, risk and performance, hundreds of CIOs have empowered value conversations centered on cost-for-performance, business-aligned portfolios, investments in innovation, and enterprise agility. The tradeoffs they've illuminated changed the tone of their meetings and instilled a business mindset in IT decisions. By reading this book, you'll discover and learn the following:

- A practical, applied framework — called Technology Business Management — for creating and using shared facts to make better decisions about people, technologies, services, and investments.
- A standard taxonomy of resources, technologies and services for CIOs to translate between IT, financial, and business perspectives.
- Creating transparency to empower decision makers, demonstrate cost-efficiency, shape demand and plan in step with the business.
- What your technology business model says about the value you deliver and the disciplines you employ.
- How to shift from project portfolio management to service portfolio management to both improve alignment and adopt more agile approaches to innovation and development.
- How to optimize run-the-business spending by optimizing infrastructure, outsources, labor and services and rationalizing your portfolios for better alignment.
- How to improve your ability to change the business by better governing innovation investments and improving enterprise agility.
- How to create and execute a roadmap for improving data and decision-making capabilities over time while reaping rewards at every stage of maturity.

Format: Kindle, Hardcover

Publisher: BookBaby (September 8, 2016)

ISBN-13: 978-0997612745

ISBN-10: 9780997612745

More Information

7.5 A Journey Through the Systems Landscape

by

Harold "Bud" Lawson

From the Amazon Website:

Systems are everywhere and affect us daily in our private and professional lives. We all use the word "system" to describe something that is essential but often abstract, complex, and even mysterious. However, learning to utilize system concepts as first-class objects as well as methodologies for systems thinking and systems engineering provides a basis for removing the mystery and moving towards mastery even for complex systems. This journey through the Systems Landscape has been developed to promote learning to "think" and "act" in terms of systems. A unique aspect is the introduction of concrete system semantics provided as a "system survival kit" and based upon a limited number of concepts and principles as well as a mental model called the system-coupling diagram. This discipline-independent presentation assists individuals and is essential for building a learning organization that can utilize a systems approach to achieving its enterprise goals. The eight chapters are presented as stops along a journey that successively build system knowledge. Each chapter terminates with a Knowledge Verification section that provides questions and exercises for individuals and groups. Case studies reflecting the utilization of the system related concepts, principles and methodologies are provided as chapter interludes.

Format: Paperback

Publisher: College Publications (June 8, 2010)

ISBN-13: 978-1848900103

ISBN-10: 1848900104

More Information

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8. EDUCATION AND ACADEMIA

8.1 New Online and On-Campus Bachelor's Degree in Systems Engineering at Regent University - Virginia Beach, USA

Regent University's undergraduate program in Systems Engineering leading to a Bachelor of Science degree (B.S.) was launched in the fall of 2018, and is designed to produce the next generation of systems engineers who are equipped and ready to deal with the socio-technical challenges of the future.

This program is a landmark for Regent University. While Regent launched computing related degrees in information systems, computer science, and cybersecurity in recent years, it has now entered the world of engineering education for the first time in its 40-year history by launching undergraduate programs in systems engineering and computer engineering. These engineering programs are offered by the Department of Engineering and Computer Science, under the College of Arts & Sciences.

This program is of some significance to the discipline of systems engineering as well. This is one of the first times that a University has launched systems engineering as one of its first engineering programs. While there are many graduate programs in systems engineering in the USA and around the world, there are only a handful of undergraduate programs in 'Systems Engineering' (not including programs where 'systems engineering' appears in the program name along with 'industrial engineering', etc.).

Other distinctive features of Regent's undergraduate program in systems engineering are highlighted below:

- This is one of the first undergraduate systems engineering programs that can be taken fully online from anywhere in the world. The entire curriculum and all courses are designed primarily for asynchronous online delivery. The courses can also be taken on-campus at Regent University's Virginia Beach campus where they will include face-to-face interactions with the instructor.

- The program takes a 'digital engineering' approach, with a particular focus on model centric systems engineering. Many of today's complex systems are being designed and developed in a global distributed environment utilizing digital resources. Students get exposed to this environment during their undergraduate program. They are also prepared to deal with new technologies and systems of the future that are not fully known today.

- The curriculum and course content are contemporary, and heavily influenced by the latest developments and products of systems engineering. These include the Guide to the Systems Engineering Body of Knowledge (SEBoK), the Graduate Reference Curriculum for Systems Engineering (GRCSE), the International Council on Systems Engineering (INCOSE) *Systems Engineering Handbook*, and *Atlas: The Theory of Effective Systems Engineers*.

- While the graduates of the program are expected to launch their systems engineering careers in entry level systems engineering positions, the anticipation is that they would eventually grow into leadership positions in systems engineering. The program is designed to offer students a long-term leadership perspective, and to look beyond their initial roles and responsibilities in industry.

- The current focus of Regent University's systems engineering education is at the undergraduate level; a minor in systems engineering is likely to be launched next. Eventually, graduate certificates and graduate programs in systems engineering are likely to be considered.

Program Coordinator: Dr. Devanandham (Deva) Henry, Ph. D

Email: dhenry@regent.edu

More information

8.2 Johns Hopkins University Whiting School of Engineering

The part-time and online programs at Johns Hopkins Engineering give working adults a convenient way to advance their education and competitiveness in twenty-one traditional and newly emerging fields.

Instructors working at the top of their industries impart cutting-edge knowledge and real-world skills in collaborative, interactive learning environments—providing students with a unique opportunity to forge lasting professional connections as they work, study, and maintain a manageable work-life balance.

As the part-time arm of the Johns Hopkins Whiting School of Engineering, and one of the largest continuing education schools in engineering in the United States, they can provide our students with flexibility to earn master's degrees and certificates while they continue working.

Johns Hopkins University has a ninety-year tradition of providing evening education for the technical workforce.

More Information

9. SOME SYSTEMS ENGINEERING-RELEVANT WEBSITES

The Quality Portal

The Quality Portal contains articles, templates, charts and explanations of several quality engineering and quality control concepts. Topics include: analytical hierarchy process (AHP), quality function deployment (QFD) and Pareto analysis.

http://thequalityportal.com/

Systems-Thinkers

Systems-Thinkers is a resurgence of a lost database of textbooks on Systems Thinking. The updated site now contains articles on Systems Thinking including topics such as 'Visualization of Relationships'. The site also contains a forum and resources tab containing information and references of interest to the field.
http://systems-thinkers.org

Worlds of Systems, by Dr. John Boardman and Dr. Brian Sauser

World of Systems is a blog written by authors John Boardman and Brian Sauser containing information on system thinking concepts from some of the key influences in systems thinking. Text from the site states: 'Systems thinking lies at the conjunction of two phenomena. The first is the amazing verity that we can think at all. We can even think about thinking! But as the song goes, "If we can solve any problem, why do we lose so many tears?" In a very real sense, we are no better off for our thinking.'

The site provides access to download SystemiTool- a free software tool that supports the creation, editing and portrayal, in the form of a storyboard of scenes, of systemigrams.
http://www.boardmansauser.com/index.html

10. STANDARDS AND GUIDES

10.1 The MITRE Systems Engineering Guide

The primary purpose of the MITRE Systems Engineering Guide (SEG) is to convey The MITRE Corporation's accumulated wisdom on a wide range of systems engineering subjects—sufficient for understanding the essentials of the discipline and for translating this wisdom into practice in your own work environment. The MITRE SEG has more than 600 pages of content and covers more than 100 subjects. It has been developed *by* MITRE systems engineers *for* MITRE systems engineers. Systems engineering is a team sport, so although the SEG is written "to" a MITRE systems engineer, most of the best practices and lessons learned are applicable to all members of a government acquisition program team, whatever their particular role or specialty.

Download the guide book for free here.

10.2 CMMI® Institute Extends CMMI® V2.0 to Include Services and Supplier Management

On 04 December 2018, CMMI Institute expanded its Capability Maturity Model Integration (CMMI)® V2.0 product suite, adding Services and Supplier Management views to the model's globally recognized set of best practices, benchmark tools, appraisal and performance measurement guidance. The CMMI V2.0 product suite enables organizations to analyze and appraise internal operations, and helps organizations measure their capabilities against best practices, pinpoint areas of improvement and achieve higher performance.

Designed to optimize business performance and achieve measurable results, CMMI Development V2.0 was first released in March of this year. In addition to product development, CMMI V2.0 now includes views that advance selection and management of suppliers as well as delivery and management of internal and external services. Today's announcement continues CMMI Institute's commitment to advance CMMI V2.0 and help organizations understand and improve their capabilities—in people, processes and technologies—across every facet and function of the enterprise.

Keeping with the goal to gain better, faster business results, additional product suite improvements include:

- Significant enhancements to the CMMI V2.0 model viewer user experience
- Improvements and clarifications to the performance-based appraisal method, along with brand-new appraisal toolkits
- New training courses and materials that teach new existing users how to assess, improve, and sustain process capability and performance, including an eLearning model upgrade course to complement the instructor-led option

More Information

11. SOME DEFINITIONS TO CLOSE ON

11.1 Taxonomy

1. The study of the general principles of scientific classification
2. Orderly classification of plants and animals according to their presumed natural relationships

Source: Merriam Webster Dictionary

11.2 Schema

1. A diagrammatic presentation, a structured framework or plan
2. A mental codification of experience that includes a particular organized way of perceiving cognitively and responding to a complex situation or set of stimuli

Source: Merriam Webster Dictionary

11.3 Ontology

1. A branch of metaphysics concerned with the nature and relations of being, deals with abstract entities.
2. A particular theory about the nature of being or the kinds of things that have existence

Source: Merriam Webster Dictionary

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12. CONFERENCES AND MEETINGS

For more information on systems engineering related conferences and meetings, please go to our website.

The featured conference for this edition is:

International Conference on Recent Advances in Engineering and Technology (ICRAET)

18 - 19 January 2019, Langkawi, Malaysia

The 531st International Conference on Recent Advances in Engineering and Technology (ICRAET) will be held on 18th - 19th January, 2019 at Langkawi, Malaysia. ICRAET brings innovative academics and industrial experts in the field of Engineering and Technology together in a common forum. All registered papers at the various conferences are published by the World Research Library and will be submitted for review for indexing by Google Scholar.

The primary goal of the conference is to promote research and developmental activities in Recent Advances in Engineering and Technology. Another goal is to promote scientific information interchange between researchers, developers, engineers, students, and practitioners working in and around the world. The conference is held every year and is a platform for people to share views and experiences in Recent Advances in Engineering and Technology related areas.

Register for the conference here.

13. PPI AND CTI NEWS

13.1 Randy Iliff Joins Team PPI

We are excited to announce that **Randall (Randy) Iliff** has joined the PPI team as a Principal Consultant, assuming roles in both training and consulting. Based in Madison, WI, USA, Randy will be assisting PPI clients worldwide to realize their ambitions.

Randy brings a unique body of developmental insight applicable across a wide range of enterprise, engineering and managerial efforts, thanks to extraordinary mentors, immersion in great innovation cultures, and decades of diverse application experience. This insight enables Randy to excel in many roles, including those as a project manager, system engineer, new product development leader, instructor/ mentor and consultant.

Randy is an effective contributor anywhere along the life cycle of a system from first-concept through system retirement but is perhaps most valued for his ability to precisely match development approach to the needs of any given development task. Randy's skill at quickly reading and responding to inherent development needs allows him to drive success across diverse aerospace, medical, telecom, scientific and consumer markets.

Randy holds a Bachelor of Science in Engineering from Michigan State University, and a Master of Science in Systems Management from the University of Southern California. He is also the beneficiary of immersion in a series of great cultures:

- Randy was a member of the highly-regarded Advanced Development Group at McDonnell-Douglas Astronautics Company in the late 1970's, where he learned "skunkworks" thinking from Apollo-era design engineers.
- He was part of the Martin-Marietta Denver Aerospace Group in the 1980's, a culture revered for their ability to manage complex development programs. At Martin-Marietta, Randy learned the art of conducting program management in harmony with systems engineering, and gained skill in a wealth of supporting disciplines such as Integrated Logistics Support, Reliability/Maintainability/Availability, Configuration Management, and Change Review.
- During the 1990's Randy was a key player in Motorola's transition from excellence as a manufacturer of devices to one of emerging excellence as a system integrator. In addition to providing consulting guidance, Randy developed and delivered an immersive program of training that greatly accelerated the corporation's transition.
- More recently, Randy spent almost 9 years with the product development firm bb7, where he helped guide a rapidly-growing organization conducting roughly 250 projects per year across an enormous range of scales and markets. This "commercial skunkworks" exposure has proven invaluable when time and schedule pressures are intense.

- Thanks to roughly twenty years spent in a consulting role, Randy has also been "inside" a much larger number of organizations and cultures worldwide. The combination of deep immersion and broad exposure enables Randy to select from the very best approaches available.

As an example, Randy drew upon deep understanding of inherent development needs and systems engineering capabilities to define a tailored approach to development effort on the IceCube Neutrino Telescope project. Application of this "sound but minimalist" development approach enabled an academic team to commission a $250 Million USD instrument at the South Pole ahead of schedule, under budget, and comfortably surpassing required technical performance. The instrument has proven extraordinarily reliable in service and has already delivered breathtaking science such as the first detection of extra-Galactic neutrinos and confirmation of the link between gamma rays and neutrino particle generation.

A disruptive innovator with a disciplined mind, Randy was a natural fit at the award-winning product design firm bb7 where he served in the role of Systems Engineer, then as Director of Strategic Methods, and eventually Vice President. Randy helped guide bb7 strategy, vision and operating design of the organization during a period of extraordinary growth. While at bb7, Randy led several major new product development efforts, provided development strategy and analysis support to dozens more, and in four cases helped clients discover, protect and develop multi-billion-dollar opportunities. He also planned, launched and managed a third business unit within bb7 dedicated to sharing the organization's experience via consulting and training.

Early on, Randy discovered the joy of helping others, and during thirty years of course development and delivery he has enriched and inspired more than ten thousand PM, SE, and Product Development professionals worldwide. He is a regular guest speaker and lecturer at the University of Wisconsin-Madison. Randy's Spring 2009 Tong Biomedical Distinguished Entrepreneur Lecture Series presentation “Unlimited Potential – The Power of Mind in Design” was so highly regarded that it became a recurring lecture attended by all who enter the biomedical engineering design program.

Along the way, he helped launch the major engineering professional society INCOSE, where he remains active at the local, national and international levels. Among other roles, he champions that society's strategic relationship with another major professional organization (PMI), and was key in bringing MIT research on PM and SE integration methods to publication in the 2017 book "Integrating Program Management and Systems Engineering: Methods, Tools and Organizational Systems for Improving Performance".

Randy's lateral thinking and ability to connect technologies, products and businesses is exceptional, but those who know him well attribute much of his success to the ease with which he interacts with people at all levels of an organization. His combination of low ego and high desire to serve others is increasingly rare.

Among his other passions Randy is keen on photography, and his work has been featured in a number of exhibitions throughout the US Southwest.

13.2 Institute for Process Excellence (IpX) and Project Performance International (PPI) Announce Strategic Collaboration

January 7th, 2019 - IpX and PPI have entered into a strategic collaboration to expand IpX product offerings to include PPI's globally and industry-renowned 5-day Systems Engineering public and onsite training courses as part of the IpX's catalog starting in Q1 of 2019.

This new strategic collaboration will focus on optimizing the natural interdependencies and alignments between Enterprise Configuration Management and Systems Engineering in helping companies achieve Integrated Process Excellence.

About Project Performance International:

The mission of PPI is to improve the performance of its clients and the lives of their people by improving the practice of engineering, based on systems thinking, and using the principles and methods of systems engineering.

PPI is an industry leader in Systems Engineering and Requirements Engineering training and discipline definition, with over 20 years of direct involvement in the development of the latest international standards, and many other initiatives. PPI has contributed to society through the training of over 14,000 professionals worldwide, working in almost every imaginable application domain of engineering, from aerospace to motor racing.

PPI's training philosophy is to intensely focus on sound principles based on historical evidence, and on the astute application of these principles, therefore creating the greatest possible value for the enterprise. The PPI team includes three former INCOSE chapter presidents and a current INCOSE chapter president. PPI Managing Director, Robert Halligan is a former member of the Board of Directors of INCOSE, a former INCOSE Ambassador, and a former President of the Systems Engineering Society of Australia. He is an Honorary Member of INCOSE Brasil, and of the Korean Council on Systems Engineering. Another PPI team member of note is Mr Randall Illif, who was a Founding Member of INCOSE 26 years ago, served as Chair of the Commercial Practices Working Group and remains active to this day as the INCOSE Liaison to the Project Management Institute (PMI).

For more information visit: www.ppi-int.com

About the Institute for Process Excellence:

IpX is best known for the creation of the industry changing CM2 certification program initiated in 1986. Today, IpX remains the global enterprise standard for configuration and change management. CM2 provides a comprehensive methodology for managing the configuration (hierarchical set of information) of a product, system, and/or service throughout its life. As product complexity increases and organizations become more reliant on their supply chains, managing change throughout the organization and the supply chain is an increasing challenge.

IpX services sector focuses on enterprise-wide changes that produce sustainable digital transformation and functional business improvements. Our industry leading True North Calibration model provides the methods to navigate the journey of complexities within today's environment. IpX's mission is to help clients plan and achieve their transformation strategy, improve their core business and operating standards, embrace the digital wave, maximize efficiency, and implement sustainable growth initiatives.

IpX has a rich domain knowledge, solutions and expertise to help organizations implement phased and manageable initiatives where business results are dependent on people shifting their behaviors and mindsets to achieve sustainable value.

For more information visit: www.ipxhq.com

13.3 PPI Reaches 40!

Countries that is! With delivery of our "systems approach to design" training in Doha, Qatar last month, PPI has now delivered systems engineering training in forty countries. This Doha training was delivered to 21 engineering professionals in a high-tech start-up company situated at the Qatar Science and Technology Park, an innovation hub supporting technology-based entrepreneurship ventures in Qatar.

13.4 Five More Systems Engineering Management US Courses for 2019

We have added five more in-depth Systems Engineering Management 5-day course deliveries {link to website page}s to our 2019 USA training program, in Orlando (18-22 March), Detroit (8-12 April), Seattle (24-28 June), Washington DC (9-13 Sep. and San Francisco (2-6) Dec., all led by PPI superstar Randy Iliff. The diagram below indicates the scope of the course, to which can be added a strong leadership element. We hope to see you there.

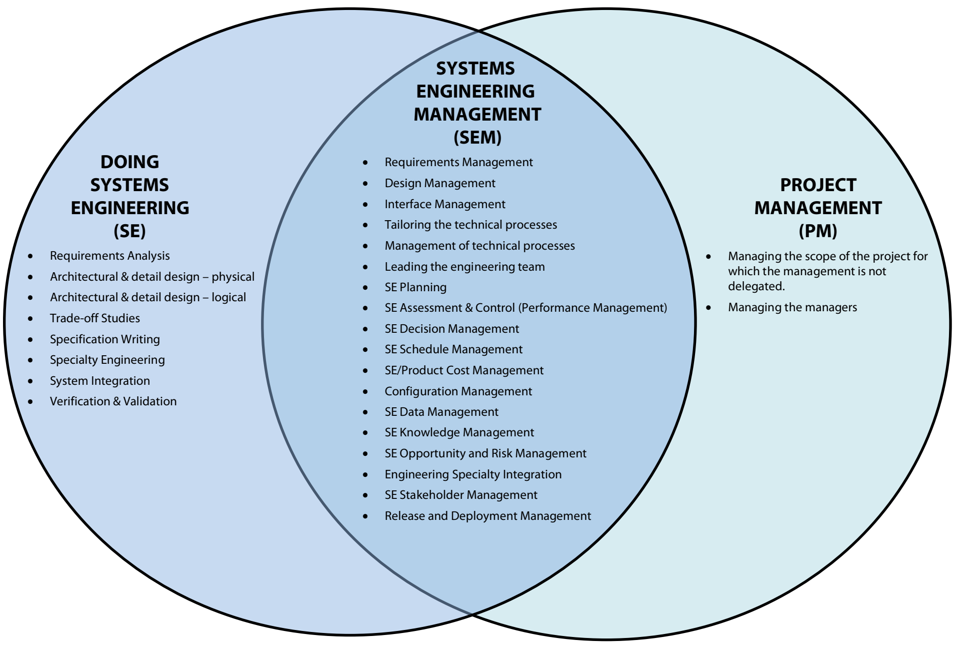

Figure: Systems Engineering - Systems Engineering Management - Project Management Relationships

14. PPI AND CTI EVENTS

On-site systems engineering training is being delivered worldwide throughout the year. Below is an overview of public courses. For a full public training course schedule, please visit https://www.ppi-int.com/course-schedule/

Systems Engineering 5-Day Courses

Upcoming locations include:

- Melbourne, Australia (P006-793)

  11 Feb - 15 Feb 2019

- Stellenbosch, South Africa (P006-771)

  01 Apr - 05 Apr 2019

Requirements Analysis and Specification Writing 5-Day Courses

Upcoming locations include:

- Pretoria, South Africa (P007-474)

  28 Jan - 01 Feb 2019

- Bristol, United Kingdom (P007-479)

  10 Jun – 14 Jun 2019

Systems Engineering Management 5-Day Courses

Upcoming locations include:

- Munich, Germany (P1135-159)

  25 Feb – 1 Mar 2019

- Melbourne, Australia (P1135-169)

  29 Apr – 3 May 2019

Systems Engineering Overview 3-Day Courses

Upcoming locations include:

- Las Vegas, Nevada, United States of America (P884-7)

  15 Apr – 17 Apr 2019

Requirements, OCD and CONOPS in Military Capability Development 5-Day Courses

Upcoming locations include:

- Melbourne, Australia (P958-57)

  04 Mar – 08 Mar 2019

- Washington, D.C., United States of America (P958-59)

  13 May - 17 May 2019

Engineering Successful Infrastructure Systems (ESIS5D)

Upcoming locations include:

- Detroit, MI, United States of America (P2005-1)

  25 Mar – 29 Mar 2019

Architectural Design 5-Day Course

Upcoming locations include:

- Pretoria, South Africa (P1768-19)

  06 May - 10 May 2019

CSEP Preparation 5-Day Courses (Presented by Certification Training International, a PPI company)

Upcoming locations include:

- San Francisco, CA, United States of America (C002-81)

  11 Feb - 15 Feb 2019

- Bristol, United Kingdom (C002-91)

  04 Mar - 08 Mar 2019

Medical Device Risk Management 3-Day Course

Upcoming locations include:

- Berlin, Germany

  18 Mar - 20 Mar 2019

- Boston, MA, United States of America

  09 Apr - 11 Apr 2019

Other training courses available **on-site** only include:

- Project Risk and Opportunity Management 3-Day
- Managing Technical Projects 2-Day
- Integrated Product Teams 2-Day

- Software Engineering 5-Day

15. UPCOMING PPI PARTICIPATION IN PROFESSIONAL CONFERENCES

PPI will be participating in the following upcoming events. We support the events that we are sponsoring and look forward to meeting old friends and making new friends at the events at which we will be exhibiting.

The INCOSE International Workshop 2019

(Participating)

Date: 26 - 29, 2019

Location: Torrance, California USA

Systems Engineering Test and Evaluation (SETE) Conference (SETE19)

(Exhibiting)

Date: 29 April - 1 May, 2019

Location: Canberra, Australia

The INCOSE International Symposium 2019

(Exhibiting)

Date: 20-25 July, 2019

Location: Orlando, USA

EnergyTech Conference 2019

(Exhibiting)

Date: 21-25 October, 2019

Location: Cleveland, USA

The INCOSE International Symposium 2020

(Exhibiting)

Date: 18-23 July, 2020

Location: Cape Town, South Africa

Kind regards from the PPI SyEN team:

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