

# CONCEPT OF OPERATIONS (ConOps) of a SYSTEMS ENGINEERING EDUCATION COMMUNITY (SEEC)

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## **Preface**

This report has been prepared by Jack Ring, Innovation Management, Scottsdale, AZ and A. Wayne Wymore, University of Arizona, Tucson, AZ. The following people assisted in the development of this document: John Boardman, Phil Brown, Dennis Buede, John Clymer, Allen Fairbairn, Rob Leibrandt, Brian Mar, Bill McCumber, Herm Migliore, Peter Sydenham and Bob Tufts.

## 1. Introduction

The development of a ConOps for a Systems Engineering Education Community was motivated by the Education Measurement Working Group (EMWG) of the Education and Research Technical Committee, International Council On Systems Engineering. The EMWG was formed to make systems engineering education a proven, value-adding, activity that matures in a systematic manner.

Initially, the EMWG intended to design a framework with which academic institutions could self-assess their capability maturity level and pursue targeted self-improvement. However, during the International Workshop, January, 1999, EMWG participants questioned the presumption of 'academic institutions' and highlighted three major considerations: a) SE education needs are broader and more urgent than can be satisfied by academic institutions alone; b) significant improvement in the cost effectiveness of systems engineering education is necessary and the improvements must be made quickly, which is feasible if the systems engineering education community (SEEC) is systemized, and c) rating systems that focus on the value a customer may receive (e.g. Michelin Guide for hospitality sites and Moody's ratings of commercial investment bonds) are more meaningful than are the 'capability maturity' class of rating systems that are more concerned with supplier process than with actual value delivered to the customer (e.g. ISO9000, Baldrige Award and the several "CMM's"). Examples of rating systems distinctions are given in Attachment 1, Alternative Assessment Systems.

Three conclusions followed. First, the SE community needs a rating system that: a) is rooted in customer value, b) has the acuity to assess not only the actual performance but also the potential improvement in performance that can be expected from contemplated changes, and c) is buffered against subjective, destructive judgments. Second, the SE education community must include more sources of learning and a greater variety of learning environments than the typical university can provide. Third, the education providers alone cannot solve these problems. Rather, SE practitioners and SE beneficiaries (such as employers and system projects sponsors) must take action to help.

The EMWG decided to apply SE practices to its mission by formulating a Concept of Operations (ConOps) for a systems engineering education community (SEEC). The ConOps was produced in Review Draft form in mid-1999 and was accepted as an EMWG working paper in the January, 2000 workshop. A summary paper was included in the INCOSE 2000 Conference Proceedings. This paper presents further regarding the ConOps and its rationale.

### 1.1. Purpose and Usage of a ConOps

A ConOps describes how a community intends to use a contemplated system as a means to mitigate or suppress an actual or anticipated problem situation. A ConOps serves to converge multiple stakeholders toward a common image and understanding of the requested system.

The viewpoint of a ConOps is from the outside-in. A ConOps describes both the stimuli to which the intended system is expected to respond and the effect the responses are intended to have on the situation. Because it describes a system of the future, a system yet to be designed, it is necessarily speculative - a vision -- though hopefully not an hallucination. It tells a story, reflects out-of-the-box thinking and is not concerned with immediate perceptions of feasibility.

A ConOps avoids assumptions about the internal content and structure of the eventual system. This is done to avoid getting lost in detail, avoid premature feasibility (mis)judgements and preclude the early insertion of pet design concepts. Such avoidance is demonstrated in this ConOps by placing all observations about possible content and structure in appendices for consideration by designers but not as part of the ConOps baseline.

To many readers, and especially to system designers and developers, a ConOps can be irritatingly vague, presumptive or unrealistic. But a ConOps should be judged solely on how well it reflects the needs of the intended benefactors. We trust that the reader will evaluate this ConOps in that light.

The ConOps is intended to be useful:

- To prospective customers of the SEEC for validation that the concept herein responds to their needs and preferences or for solicitation of improved expressions of needs and preferences.
- For stimulating consideration of novel concepts and technologies potentially pertinent to the SEEC and, particularly, to its collaborative planning and control system.
- As a baseline for thusly enlightened functional analysis and other steps in the process of systems engineering an SEEC.
- As a baseline for interrelating the work of the EMWG with other INCOSE endeavors.

Although the ConOps is a free standing document it has important relationships with other INCOSE interests including ISO/IEC 15288, EIA 632, the INCOSE SE Handbook and the Guide to SE Body of Knowledge as well as the special INCOSE project charged with producing a Taxonomy of SE Competencies

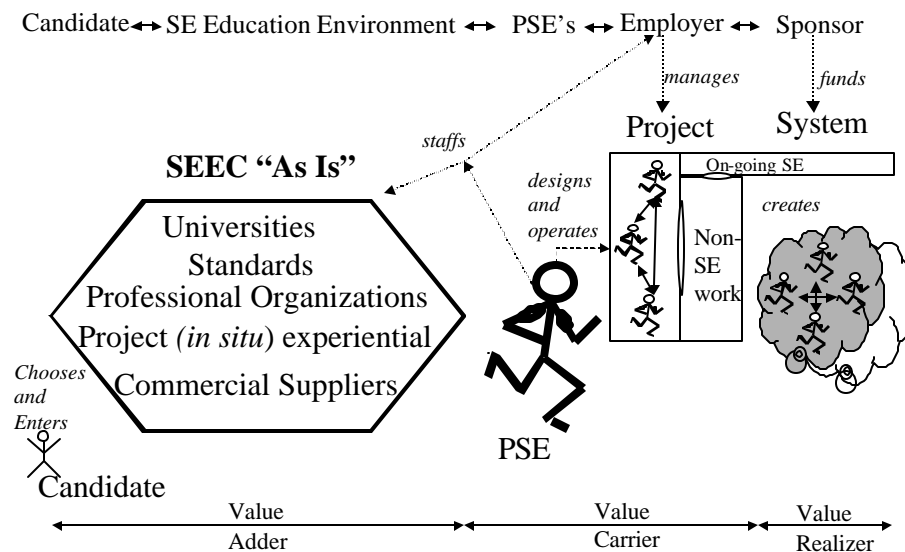
Also, the ConOps anticipates that actual capability maturity assessments of various AS IS situations throughout the INCOSE community will reveal respective opportunity for and direction of competency development. This ConOps prepares for the next logical step after assessment revelations. It is concerned with how an SEEC can respond to all these factors in an adequate, accurate and timely manner which translates to several fold better, faster, and cheaper than are the current set of educational opportunities.

## 2. SE Education: The Problem Space

*Education is not the filling of a vessel;  
it is the kindling of a flame.  
Socrates*

### 2.1. Context of an SEEC

An SEEC in context as shown in Figure 1.



**Figure 1. Context of an SEEC**

The SEEC is located within the hexagon on the left. All else is SEEC context. The context starts (reading from upper right to upper left) with a Sponsor needing a new system.

**Sponsor:** The Sponsor funds the system, including its development. The sponsor and related beneficiaries realize value from the system after it is delivered, operated and adapted to the operational situation [Ring 98].

**Employer/Contractor:** The sponsor typically relies on an Employer/Contractor to manage the project that creates the system. The Sponsor selects the Employer who convincingly proposes to accomplish the Project "better, faster, cheaper" than competitors.

Ideally, Sponsors and Employers share the risks inherent in creating the system and share the rewards that flow from the value exhibited by the system when operational.

**Project:** The project is where time, resources, competencies, goals, status reviews and activities are mixed together and results emerge in terms of Quality, Cycle Time, Cost and Learning. For purposes of this paper a project is viewed in three parts; a front-end part consisting mostly of SE work, an on-going SE part that encompasses development, deployment and adaptation, and a third part that consists of the Non-SE work such as component engineering, integration, test, training, deployment, activation and adaptation. For clarity, project management and other administrative tasks are not shown. Although projects vary widely, heuristics regarding successful projects indicate that the front-end part consumes about 5% of the project budget and the on-going part consumes another 5% to 10%.

**Practitioners of SE (PSE's):** As part of the overall project, PSE's, as employees or subcontractors, collaboratively design the SE project (perhaps documenting the scheme as a Systems Engineering Management Plan (SEMP)). Then PSE's operate the SE project by forming relationships with one another and with other people who are in non-SE roles on the project. The degree to which PSE's are effective in a project setting is modulated by three factors:

- Competencies of individual PSE's.
- Collaborativeness (the emergent competencies of the set of PSE's on a project) and immunity to situations which tend to disturb and degrade individual and workgroup enthusiasm
- SE project work climate, method and tooling. The project work climate and overall culture is generally created by the employer and influenced by the system project's sponsor. The methods and tooling may not match the SE challenge. Mismatch can affect productivity and innovation by a factor of 10 or more for both the PSE's and other project members [Livingston].

**SE Artifacts:** SE artifacts (aka work products) are the results of SE work. The SE artifacts inform PSE's and the Non-SE performers on the overall project who then produce the balance of the deliverable artifacts that complete the project. Collateral outputs of a project embellish the SE body of knowledge. Yet other outputs of the project are by-products that may be benign or may be toxic waste and must be purged from the body of knowledge.

**SEEC "As Is":** Within this context the SEEC adds value to PSE participants by increasing each PSE's competencies (repertoire of capabilities and proficiency level in each).

The value-added to a PSE is considered latent until the PSE produces artifacts. Only when a competency is applied can the value-added be realized. Consequently, value-added is an emergent property rather than a guaranteed effect of a resource. As will be discussed later in this paper, this fact significantly influences the envisioned SEEC planning and control system.

The SEEC consists of at least five types of providers;

1. universities and other academic centers,
2. commercial suppliers of SE learning,
3. SE relevant standards bodies,
4. professional organizations,
5. *in situ* or on-the-job-training (OJT) situations on real projects.

These five types of providers are necessitated by the level of understanding of the foundations, tools and skills required by PSEs, the span of domain knowledge required by PSE's and the spectrum of learning styles exhibited by PSE's. Currently, this five part montage exhibits gaps and overlaps in subject matter, learning environment offered and learning style supported.

Although academic centers are striving to create more realistic learning environments [Axelband et al], [Frey, et al], [Kurstedt et al], [Lang, et al], we believe that structural and cultural limits in academia will preclude universities and related laboratories from being sufficiently responsive.

The reader should note that, in the interest of readability, Figure 1 does not illustrate the fact that the Project (*in situ*) experiential learning can be congruent with the Project operations on the right side of the figure. All Projects may be used as SE learning environments unless project considerations make this imprudent.

**Candidates:** The SEEC processes Candidates to produce PSE's. A small percentage of candidates will experience the SEEC for the first time but the majority of Candidates will be recycling through the SEEC multiple times as they incrementally augment their respective capabilities. One mode of recycle is the Real plane where the practitioner physically returns for more experiences. The more prevalent mode of recycle, however, is the Reflection plane wherein a practitioner imagines, recalls and reaches deeper understanding [Schon] without returning to the original learning location. The more advanced PSE may transit an SEEC, in real or in reflection, more than a thousand times during a 40 year career.

Each cycle through the SEEC increases basic SE competencies and respective proficiency levels. Also, each cycle increases a PSE's personal learning power (rate of adding competencies and increasing proficiencies) as the PSE's level of awareness increases and he/she "learns to learn" [Wymore 69]. Learning to learn is especially important during *in situ* sessions of direct project work.

The SEEC must span the needs not only of PSE's on projects but also of PSE's who act as employer managers and PSE's who act as principals in the SEEC provider organizations. The more capable PSE's should be able to contribute effectively in any of these roles. The SEEC must also provide opportunities for engineers of other persuasions to gain competencies to work with PSEs.

## 2.2. Key Success Factors.

Four Key Success Factors are evident from the foregoing description.

**KSF 1: The Practitioner.** Systems engineering (SE) is not a bounded, and perhaps not boundable, activity but can be imagined as "qualified people applying a body of knowledge to problem situations in order to produce a solution in the form of a problem suppression system model." Each problem situation or problem suppression system is new, rarely the same as previously experienced. Rather, the participants actually are practitioners of systems engineering (PSE's) similar to, as described by [Schon] practitioners in legal, medical, and other professions. Practitioners, a) are familiar with their respective body of knowledge, b) judiciously select and apply this knowledge in a series of information assimilation sessions punctuated by design decisions, and c) vigilantly pursue the specification of an effective solution, while d) pursuing improved practices on their personal part and contributing to their community's body of knowledge.

**KSF 2: Agility.** Many PSE's have not experienced a variety of domains and methods. Increasingly, PSE's in the future must be competent to examine a variety of problem spaces and prescribe components and their relationships (architecture) that comprise effective solution systems for the specific situation. Estimates of the future, by the World Future Society and others, indicate that PSE's must cope with problem situations that are getting bigger, nastier and more complicated. Likewise solution technologies are proliferating at a pace recently characterized as "option shock." Accordingly, agility is the game of the future. Agility is the ability to thrive in an environment of unpredictable change [Dove].

To create agile systems a PSE must: a) tailor the systems life-cycle model and SE process model, b) design for agility, and c) be personally agile in order to adapt to a variety of project team cultures and solution technologies [Senge].

This means that PSE's must be educated not only about doing SE and interrelating with others to accomplish the whole of systems engineering but also about being change proficient – how proactively to change their own body of knowledge, how to change the methods and processes by which they apply the knowledge and how to change the content and style of their interrelationships with others.

Similarly, education environments must be sufficiently agile as must SE managers.

**KSF 3: SEEC Requisite Variety.** PSE's need more kinds of learning environments than academic institutions can provide. This does not diminish the great contribution made by professors of systems engineering but it does acknowledge the structural limitations of institution-based learning environments. It also acknowledges that a variety of other knowledge sources and learning environments are already in use by PSE's but are disjoint and do not deliver the synergistic advantages that could be delivered by a more collaborative community. The variety of learning environments is partly indicated by the broader span of subject matter that a PSE must master as compared to discipline engineers, marketing, sales or other functional specialists. As [Sydenham] pointed out, although college degrees are an indicator of SE competency a degree is not a sufficient indicator of which persons and organizations can create systems "better, faster, cheaper."

**KSF 4: The Tri-partite system.** The SEEC operates within a tri-partite SE community consisting of PSE, Providers and Payers, the latter also known as employers (or equivalent, sponsors of both PSE education and educational assets). The ConOps must include and harmonize all three aspects of this larger community and the SEEC is seen as the harmonizer as well as simply the learning delivery system.

### 2.3. Imagining the SEEC

The authors considered whether to survey and summarize the customer situation, needs and requirements or to propose positions on each of these factors and validate the positions as a follow-on.

In view of the cost and time consumed by a survey and because of prior research in this vein [Ring 94], and the material presented by F. Alvarez, K. Forsberg, J. Ring, and A. W. Wymore at the INCOSE 1994 tutorial the "propose and validate" approach was selected. The validate action is reflected, above, in the section on Purpose and Usage of a ConOps, and is presumed to be part of the requirements management task of the SEEC systems design phase that should be based on this ConOps.

**The key problem** is the lack of a unified framework among the stakeholders for;

- assessing current capabilities of PSE's,
- nominating and rating education options,
- making choices about sessions,
- scoring individual outcomes, and
- assessing the emergent levels of proficiencies exhibited by individual PSE's and workgroups..

Although many proposals and projects over the years have been aimed at improving SE education, the well meaning and highly motivated providers and beneficiaries never achieved sufficient teamwork and traction to make a significant difference. The problem has not been lack of understanding or lack of effort but lack of a unifying model of the interrelationships of the various parties involved. All stakeholders need a "Consumer-Provider Rating system" that will enable:

- Individual PSE's to make good choices about education opportunities as offered by providers and employers.

- Providers to make good choices about the environments and experiences they offer, the relationships they will sustain with other providers, the PSE's they accept, and the employers they serve.
- Employers/Sponsors to make good choices about which Providers to support and which individual PSE's are more likely to yield a good return on an educational investment. Also important are good choices regarding which collateral adaptations they need to make, internally, in order to let PSE's be most effective on projects.

In response the ConOps describes:

- The **context** of both SE performance and SE improvement in order to bound the topic and to provide a basic ontology of the situation. In essence this results in an operations model of a knowledge generation and utilization process.
- The **value added** by SE (the key types of contributions that PSE's can make to a project).
- The **performance** (range of effects on the PSE's) required of the SEEC in quantitative terms of capacity and goals.
- A set of generic **measures of effectiveness**, MOE's, applicable to SEEC performance and SE improvement.
- How the **quantification and choice-making** operations could proceed. This is envisioned as a distributed, heterarchical system (one which stabilizes rather than remaining chaotic).
- The **participants** in terms of their respective responsibilities and intents regarding improving SE.
- How the **SE community** can emerge and evolve depending on the importance of **adequate, accurate and timely information** from the perspective of each participant and the importance of enforcing the **trust/penalty rules** of the community.

Note that we do not get embroiled in defining SE nor in prescribing SE processes. Although follow-on work spawned by the ConOps may have to grapple with those specifics, a ConOps can successfully talk about the improvements that users of a system need without delving into how such a system gets created.

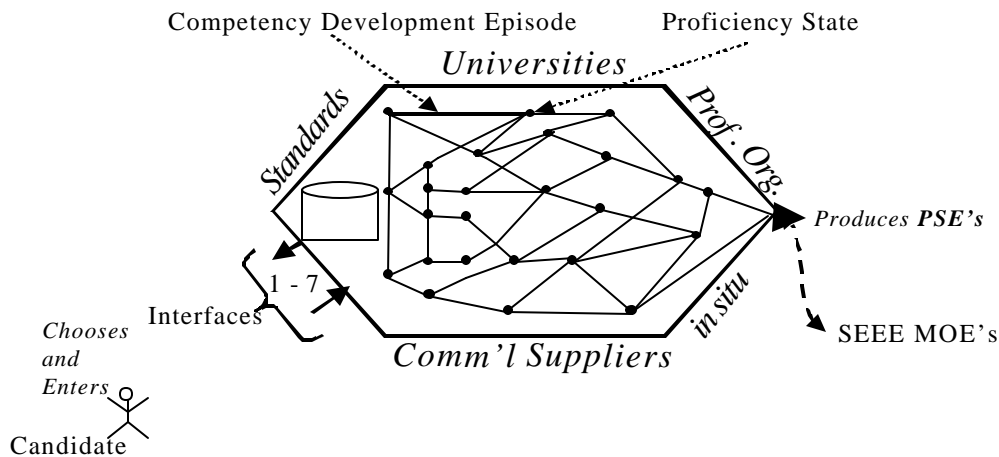
### 3. Solution Space: SEEC Operation

The SEEC: a) produces a model of itself that exhibits a high degree of fidelity to actual SEEC characteristics and properties, thus must be updated frequently, b) makes mutually beneficial choices among alternative investments and relationships and c) evolves a future learning community that maximizes the value added to each member of the community.

This ConOps does not specify the content, structure nor processes of the SEEC as have [Cornesky 1997], [Leibrandt 1999], and [Mills and Alessi 1999] but strives to give purpose and perspective to such design concepts and approaches.

#### 3.1. SEEC "To Be"

A key aspect of the ConOps is the notion of systematizing the SEEC such that the five types of disjoint providers become five subsystems in a collaborative system as indicated in Figure 2.



**Figure 2. Systemized SEEC**

The five subsystems will collaborate to create a sufficient and seamless system that would offer a set of competency development episodes to PSE's who would thereby reach heightened states of proficiency in each.

The subsystems will proactively collaborate in providing an adequate span of competencies. The subsystems may overlap in subject matter but will be more complementary in learning environments.

An appropriate metaphor may be the learning environment for "Top Gun" fighter pilots. Only so much can be learned in ground school, even with flight simulators. More is learned in actual flying and even more when practice is focused on various pseudo-threats. Then comes the real thing and the learning accelerates tremendously, even to the level, for some at least, of acknowledging that only a limited range of competencies have been mastered so far. Further, the scope exceeds "one person - one plane" because modern combat requires collaborative maneuvers. Learning extends to "sharing the risk and taking up the slack" for the good of the team. In this metaphor, the questions are; "How does a pilot, whether fledgling or advanced, know what learning experiences to pursue next?" and "Where can he/she go to gain such experiences?" and "In case alternatives exist how does he/she know which one is likely to suit his/her unique situation the best?"

We believe that the variety of learning environments that already exist provide an excellent basis for evolving the SEEC. The challenge of creating an SEEC is rooted more in accomplishing proactive collaboration than in creating new learning environments. Simplify, Integrate and Automate seems to be the applicable principle. Adequate near-term progress can be made by systemizing and harmonizing existing assets. In the longer term, say by 2005, we foresee that many learning sessions must take place "anytime, anywhere, anyhow" as contrasted to "students on campus." Current experimentation with on-line and just in time learning via the internet will open viable options by then. But these considerations are left to the SEEC system design and architecture task and need not be explored here.

### 3.2. SEEC Conceptual Interfaces

Without prescribing the content of the SEEC we can remark on the primary conceptual interfaces the SEEC should exhibit:

1. An ontology of Systems Engineering that identifies the terminology, usage and interrelationships across the stakeholder domains
2. Principles, practices, standards, heuristics and handbooks regarding systems identification, design and engineering.
3. Career progression guidelines for planning the evolution of a PSE,
4. Bill of Learning Opportunities and a Rating Scale and Procedure.
5. Choice-making decision support protocol and aids.
6. Source material for Competency and Proficiency Development (including an adult learner model as indicated in Appendix 2).
7. Dialog Facilitator that enables a PSE to engage in reflection and action learning.

Items 1 – 6 comprise an SE Body of Knowledge whereas item 7 is an SEEC capability.

#### 4. Measures of Effectiveness

SEEC effectiveness is indicated by the value received by each of its stakeholders. The SEEC operates directly on PSE's. All other stakeholders experience and realize value through the PSE's. Accordingly, the PSE's can be seen as value generators and value carriers. The concept of value refers to the effect experienced by those who use the SEEC and those who use the artifacts created by PSE's or otherwise are affected by the decisions of PSE's.

One way to consider SE value as enacted by PSE's is the recent interest in the value to a corporation of its intellectual capital. According to [Strassman], *"Skills, schooling and the experience accumulated by an individual are not necessarily a measure of that person's worth as an employee. --- It is superiority in information management that now creates economic value-added for the overwhelming majority of U.S. businesses. For that reason, it is not the salaries and wages that determine the worth of a worker, but how much economic value-added they create as an organized body in excess of the sum of their compensations. --- Why do (companies) employees, in terms of knowledge capital valuations, show dramatically different valuations? What can explain the 544 percent differences between (highly similar companies)? Such a large disparity cannot be possibly explained by any other attribute that would show up on employees' resumes."*

SE, as enacted by PSE's, is the prime mover in knowledge production and utilization. The intellectual capital of knowing how to do SE (of the appropriate flavor in the appropriate amounts, at the right times) can be as significant as noted by Strassman.

##### 4.1. SE Value Proposition

If the value of SE cannot be measured directly the value can be clarified by considering what a given situation would be like if SE did not exist [Wymore 98].

Sponsor-realized value is achieved in a generative manner. The SEEC, by turning candidates into PSE's, is a value adder. The resulting PSE's are carriers of latent value. The value realization phase is triggered when PSE's are allowed to apply their knowledge in projects. The resulting system, when operated to the benefit of the Sponsor, completes the value realization process. But this process should not be thought of as a static model. In the interest of "better, faster, cheaper" the real question is, how can the generative process be accelerated – but with fewer resources?

PSE's can affect the value both of the projects in which they participate and the systems that result, as well as the value of competency and proficiency gains from the experience. [Ring 98].

If the majority of system projects can be executed "better, faster and cheaper" with the appropriate amount of the right kind of SE then we all can benefit from being able to apply just the right amount. This does not necessarily mean that the SE work should be done "better, faster and cheaper." Some projects may benefit from more SE than might be applied otherwise and other projects may benefit from less SE. Certainly all projects will benefit from less of so called "SE" that is not, in fact, SE.

#### 4.2. PSE's are the Value Carriers

The contribution of SE is best modeled by the contribution of PSE's to the project. All other factors should be related to the PSE and manifest their influence on project outcome through the PSE's. This is an important distinction. We note that most of the literature and standards [632, 731, 15288] regarding the performance of SE focus on activities and techniques of the PSE's but do not specify the outcomes thus created.

Outcomes, of course, are fundamental to determining value from the viewpoint of the beneficiaries. -- the value of the contribution made by the right kind and amount of SE, the relative value of one PSE vs another PSE or the expected value from immersing a PSE in another cycle of learning in order to get the "new and improved" model of that PSE for the next project.

#### 4.3. Value of SE to Projects and Systems

We see the top three contributions of PSE's on a project to be:

**I. "Establishes the system ontology"** - wherein a common language is installed in (and adopted by) all project participants.

[Maturana 80] and see also <http://www.inteco.cl/biology/ontology/> describes linguistic interaction in which he constructs a model of **linguaging** – the activity in which interactors mutually orient themselves to one another and to a subject (as opposed to 'piping' presumably meaningful 'messages' back and forth at each other). As [Rubin 99] describes the Fernando Flores approach or [McDavid 99] an IBM approach or as [Warfield and Cardenas 94] demonstrated, a common language enables participants to dialog about a systems life cycle, systems terminology, issues and conflicting objectives, work products, methods and tools for analysis and synthesis and numerous other topics

Usually a generic language is installed first, followed by specific terms and names for each system that becomes the subject of a project. The generic language can be installed by academics, professional societies or standards. The balance must be done, in situ, during a specific project by PSE's who name phenomena regarding the problem space, the conceptual representation of the solution system and the logical representation of the same system. These specific PSE explain, as well, System Measures Of Effectiveness (MOE's), risks and key success factors (KSF's) then further elucidate the network of interrelationships and respective significances of all these.

**II. "Images both the problem system and the solution system"** - wherein the artifacts of SE are produced. [Evans and Patterson 98] clearly describe the concept and process of imaging a system. The following paragraph summarizes their paper but readers are strongly encouraged to carefully read their original ideas.

*The eventual solution system evolves from a conceptual understanding of the problem to a model and simulation of the problem symptoms and problem amelioration strategy. Then an initial, nearly inexplicable thought occurs regarding the solution system. It is followed by a conceptual diagram or story followed by a model and simulation followed by a set of abstractions that are interrelated in an*

*architecture. The architecture is a check of the 'wholeness of the set and enables the anticipated effectiveness of a realizable system. To preclude this evolving model from becoming incomprehensible, the few key determinants of system behavior and cost are identified. System development progresses to specifying and creating physical manifestations (aka components) and on to interconnected sets of physical manifestations that finally qualify as a deliverable system. From the first test results through the lifetime of the system the system model is updated to reflect the reality of the system in the real world.*

**III. "Converges risk and creativity to closure"** is the third contribution of PSE's wherein the few key determinants of system success are used to guide all trade-offs and judge all design proposals and design change proposals. Here PSE's deal with numerous new ideas and suggested shortcuts by other project members as well as employers and sponsors. And the PSE's must adjudicate each within the "heartbeat" of the project. Only those persons having understanding of the systems theoretic view of the design are qualified to specify the allowable sequence of design reviews and baseline reconciliations. Typically, only PSE's are qualified.

This PSE contribution continues even after the first article acceptance. Having confirmed that the set of components exhibits acceptable behavior in the pseudo-reality of the development project, PSE's next confirm that the web of components produce acceptable behaviors in the real operational environment. Also, PSE's help discern the inevitable adaptations to interfacing systems that will further benefit the users.

#### **4.4. SEEC Measures of Effectiveness**

Although the behavior of almost any system is more than the linear sum of the behavior of its elements, the fact remains that system behavior is still some function of the behavior of the elements and interrelationships. The focus must be on interrelations and elements because SE is a system composed primarily of people wherein the type and intensity of relationships are emergent behaviors that we cannot presume to change directly. Improving SE must be done by improving one or more PSE's -- Project PSE's, Manager PSE's, Sponsor PSE's or Provider PSE's -- and doing so in a way that causes the resulting SEEC to exhibit improved effectiveness rather than a way that exhibits increased conflicts and diminished performance.

The best SEEC produces a stream of the appropriate mix of practitioners for forthcoming projects and systems at minimum cost and cycle time. Accordingly, the SEEC is always changing -- continuously evolving in subject matter, learning styles, capacity and deployment patterns.

To improve PSE's, especially toward the goal of creating systems "better, faster, cheaper" the stakeholders must be able to measure and predict the effectiveness of a given or presumed configuration of an SEEC. Because the SEEC is a process that adds value to PSE's the generic MOE's for an SEEC are:

- Value Added to PSE by SEEC,
- Cycle Time of PSE learning,
- Return on (SEEC) Resources.

, The Value Added by an SEEC, however, is not measurable directly. Note this is value from the viewpoint of the systems project, not simply credit hours on a transcript. Not until the PSEs contribute to developing a system can the value of their experience in the SEEC be quantified. Consequently, PSE effectiveness must be factored into SEEC effectiveness as follows.

The generic MOE's for a PSE are;

- Fit for Purpose,
- TBO/TCO (where TBO = Total Benefit of Ownership, and TCO = Total Cost of Ownership) and

- Agility.

Substituting these three PSE factors for the aforementioned SEE Value Added factor we have:

SEEC effectiveness =

- PSE Fitness for Purpose,
- PSE TBO/TCO,
- PSE Agility,
- SEEC Cycle Time and
- Return on (SEEC) Resources, both consumed and monopolized.

However, the PSE Fit for Purpose factor is still not directly measurable. It must be determined in the context of the effect by the PSEs on the systems creation project. From the foregoing description of SE value and PSE's as value carriers we can further substitute for PSE Fitness for Purpose to get:

### SEEC MOE's

1. Increased PSE capability to language a project.
2. Increase in PSE capability to provide images (models) of both problem and solution systems.
3. Increase in PSE capability to Converge creativity to closure.
4. Increased PSE TBO/TCO
5. Increased PSE agility and change proficiency
6. Cycle Time of PSE transit through an SEEC session.
7. Return on SEEC Resources, both consumed and monopolized.

*Note that the Return on Resources MOE is a Provider concern, not a PSE concern. It indicates the likely "staying power" of a given provider subsystem because "Return" traces back to the objectives of an enterprise, according to Peter Drucker, Market standing, Productivity, Innovation and Liquidity. Include in references?*

These MOE's clarify that:

- Sponsors, Employers, PSE's and non-PSE project participants will judge the SEEC, and subsystems therein, by project MOE's
- An employer judges a PSE by System MOE's
- Project Members will judge the SE artifacts by system MOE's whereas they will judge the PSE activities by project MOE's.

Note that when the stakeholders consider a change to SEEC the net future value of the contemplated change will be the degree to which MOE's 1, 2, and 3 are enhanced as modulated by the degree to which these enhancements will "flow through" to Sponsored systems via the value carriers, the PSE's. A contemplated enhancement of the SEEC is obviously of no value if it is not relevant to PSE or Sponsor needs. Similarly, a competency or proficiency level achievement by a PSE is of no value to a given project if it is not needed on a Project.

## 5 SEEC Performance Expectations

For perspective on the scope and dynamics of the SEEC the following estimates are proposed (and must be validated or changed in the systems design phase). Estimates of the population of PSE's, Providers and Payors have not been available from INCOSE or other sources but U.S. Dept. of Labor Employment statistics enable an informed estimate of the population of workers who spend a majority of their time performing the type of work INCOSE calls systems engineering. And, consistent with commercial business practice, the world-wide estimate was generated by doubling the U.S. estimate.

*Note: We recognize that deterministic estimates, used here for ease of reading, can be misleading and that probabilistic estimates must be made in and for the system design and architecture phase.*

- PSE's constitute 2 million persons making 4 million choices per year. However, less than 500,000 of them actually utilizing an SEEC subsystem for competency development experiences annually.
- Employers in 50,000 establishments making 250,000 choices per year regarding project PSE's. Also, sending 2,000 leaders per year to utilize at least one SEEC subsystem for competency development experiences.
- Providers in 2,000 establishments making 4,000 choices per year and sending 2,000 principals per year to utilize an SEEC subsystem for competency development experiences.

The SEEC must support the planning and choice making activities asynchronously. Delivery of the competency development experiences will be mass customized for anytime, anyplace, anyway utilization.

The magnitude of the current "gap" between

- a) the SE community "as is" capability and
- b) the needs of Sponsors for "better, faster, cheaper" projects and systems

was estimated from informal interactions with more than 40 practitioners regarding the degree to which their talents were used, the time and cost of educational sessions and the degree to which they were prepared to contribute on various system project scenarios. The majority of project PSE's in our sample report that they are producing at less than 25% of their potential due to unacceptable work climates and cultures. These findings are consistent with the surveys reported in [Ring 94] and the emphasis on management involvement noted in numerous articles, book and papers.

Likewise, our preliminary estimates are that SEEC cycle times must be reduced by three fold relative to current experiences and that the SEEC must become nine-fold more capable of adding value to PSE's during the aforementioned reduced cycle times. We expect that this latter, seemingly formidable challenge may be met simply by ensuring retention and application of acquired knowledge. This, of course, is the rationale for integrating the subsystems into an on-going learning community.

Certainly a more formal and comprehensive assessment of gap size should be done. In fact, when the SEEC becomes operational it will quantify the gap frequently as a normal part of its auto-alignment of itself with its context.

At this point in the ConOps we have described only a single thread of the trajectory of an individual PSE through an SEEC and consequent performance on an SE project. We expect, however, that a team thread will be significant or even dominant because PSE's typically work in teams on an SE project. Also, a team learning environment tends to intensify focus and heighten co-learning by individual PSE's.

## 6. Collaborative Community Concept

Current literature regarding eBusiness describes supply chains (moving products up the chain to consumers), value chains (supply chain complemented with knowledge chain that moves information down the chain). These simplistic models are manifested in the real world as value webs in which numerous chains intersect at their links to form a web. These intersections occur because any one enterprise may serve more than one customer and thus is a member of several chains, simultaneously.

We see the SEEC operating as a value web consisting of instances of PSE's, Providers and Sponsors. This value web is a heterarchical network in which the parties are continually shifting the types and gradients of their interrelationship. It is presumed, but remains to be shown, that such system will be able to arrive at stable operating patterns, not being continually in chaos.

Each party in the value web will;

- be aware of its situation (e.g. PSE aware of current capabilities and opportunities afforded by increased capabilities,.
- examine options and formulate plans toward its goals,
- navigate the web to find information and services,
- gain experience and reflect on its experiences
- score themselves and others throughout the web, earning points which can serve to quantify gradients among them.

Conditions for proper citizenship on the web, thus for minimizing chaos, include:

- An intent to collaborate toward the common good.
- A common view of
  - a) product (PSEs') and process (SEEC),
  - b) roles, goals and authorities,
  - c) status and situation,
  - d) risk and reward, and
  - e) trust and penalty
- A means of negotiating across non-hierarchical relationship patterns.

### 6.1. PSE User View

A PSE, whether project, manager or provider principal, intends to select the **next best learning experience** (time period, content and type) that will meet his needs on the locus of Competency and Proficiency Level. Examples are: discovering how to perform better in a current role, qualifying for a desired role, dealing with new types of problem systems and solution systems, producing a broader set of project outcomes, improving change proficiency, improving choice making, and estimating current competencies and proficiency levels.

When making these judgments a PSE tends to consider only him/herself. His/her planning horizon is only weeks or a few months. Other factors considered include; level of personal enthusiasm (including interests), career plan, sponsor needs, provider availability, own learning style and provider prerequisites.

A PSE may decide which Provider to use and such decisions may be influenced by the views of associates, employers, and providers.

In the course of becoming world class each PSE must make hundreds of such choices among thousands of alternatives regarding the trajectory of capability development that is best for his/her purposes. The outcome of this stream of development choices -- the capability profile actually achieved - is partly determined by the practitioner's learning power, partly by the quality of choice-making and partly by luck.

To make good choices regarding his/her own development a PSE must be able to compare alternatives with respect to how each alternative is likely to produce the results.

## 6.2. Employer User View

PSE's who are also managers have additional concerns beyond their personal development. Because each cycle through an SEEC is typically funded by an employer or other sponsor, employers intend to select the a) **next best initiative** and b) **next best learning experience**. The next best initiative anticipates the employer's opportunities in the marketplace and the threats of competitors. The next best learning experience identifies the educational opportunities that align with the initiatives. For example, and employer must decide in which PSE's to invest (world class PSE's are a Make vs. Buy situation and employers are continually deciding whether to grow incumbents or to hire or subcontract for needed talent). Likewise, employers decide which providers to use. Importantly, PSE's who are also employer managers must be very aware of the behaviors they must exhibit in order to leverage a PSE's latent value-added into real value-added during the project. This may include adapting the organization's expectations, culture, work climate, associates and processes to leverage the latent value of enhanced PSE's.

When making such judgments employers typically consider the total staff.

Employers have two time horizons. One concerns selecting the best set of PSE's and conditions for a current project. The other concerns planning their SE improvement scenario in the interest of maximizing their match to their expected future.

Other factors considered include; lead time of the learning, synergy with other activities, prevailing commitments or other such choice constraints, and even corporate image.

## 6.3. Provider Subsystem User View

PSE's who are also Principals in provider subsystems have other concerns beyond their own development. Each SEEC subsystem intends to select the a) **next best reward and b) next best initiative and c) next best learning experience** as influenced by next best investment in: span of system topics (systems thinking, systems design/architecting, systems engineering, etc.), modes of performing SE, variety of education environments to be offered, competencies of principals (professors, instructors, mentors, team leaders, etc.), pattern of relations with served market (in which communities to serve), and synergy with other SEEC subsystems.

Providers must consider not only themselves but also their intended market (employers and PSE's). Their planning horizon must be months to years. Additionally, depending on the type of SEEC subsystem, other factors involved are:

- Academic = faculty, accreditation, facilities, obsolescence, research capability and contributions to the theory and practice of SE
- Professional Societies = forum, certification, obsolescence.
- Standards Bodies = stability, interoperability, obsolescence.
- Commercial Suppliers = liquidity, market standing, synergy, obsolescence.
- *in situ* = risk of interfering with customer commitments

Providers are informed not only by Employer and PSE needs but also by their own research on the next most important unknowns in the practice(s) of SE.

The provider of an *in situ* (project) environment is typically the Employer. Some believe they get a "double bang for the buck" by using their own projects as the learning environment to further competencies and proficiencies, but others, and especially their Project Managers, may have different perceptions of increased project risk and cost.

A key challenge presented by this ConOps is the notion of current education providers forming a proactive, collaborative, agile community of purposeful practice where the purpose is better, faster, cheaper capability development of PSE's and the practice consists of synergizing the various learning environments.

## 7. Multilateral Decision Concept

No singular control point exists in this 'three-body problem' situation. PSE's cannot force employers and providers to improve any more than employers can force PSE's and providers to improve. Likewise, providers are relatively powerless to demand improvements of PSE's or employers, let alone demand collaboration from other provider subsystems. Although standards authorities may attempt to regulate all the others, as do some very large sponsors and industry associations, basic system theory says that if the gestation cycle of a standard is far longer than the duration of associated knowledge cycles then the standards are largely irrelevant when finally released. In such situations standards cannot contribute to control.

Because all relationships will be elastic and reflexive, the inescapable conclusion is that the problem of improving SE requires a system for improving the SE elements and interrelations in a synergistic fashion – in other words a 'concurrent round robin' or heterarchical system.

Both the common view and the means of negotiating across non-hierarchical relationship patterns are provided by a unifying framework of information and decision.

Unified means that the system relates simultaneously to the interests of all three types of stakeholders. Because all three types of stakeholders invest in SE improvements in anticipation of satisfactory return on their investments all three need a way to anticipate the mutual interaction of their respective choices.

Information sufficient to establish the common views is available to all community members.

Decision or choice making means knowing goals, knowing options and their respective probable payoffs and selecting appropriate actions.

An SEEC, in addition to creating learning environments and fostering learning, should be the focal point for unified information and decision about appropriate learning.

Participants in the SE community have numerous individual concerns but they also have three common concerns which can be the unifying framework for improving SE. These are Time, Competencies, and Proficiency Levels.

**Time** - a calendar of events.

**Competencies** - The subjects of education and the "operators" of application. We anticipate that there are 200 to 300 distinct competencies pertinent to the whole SE community. We think the breadth of competencies is very important and often seriously understated in most SE education literature.

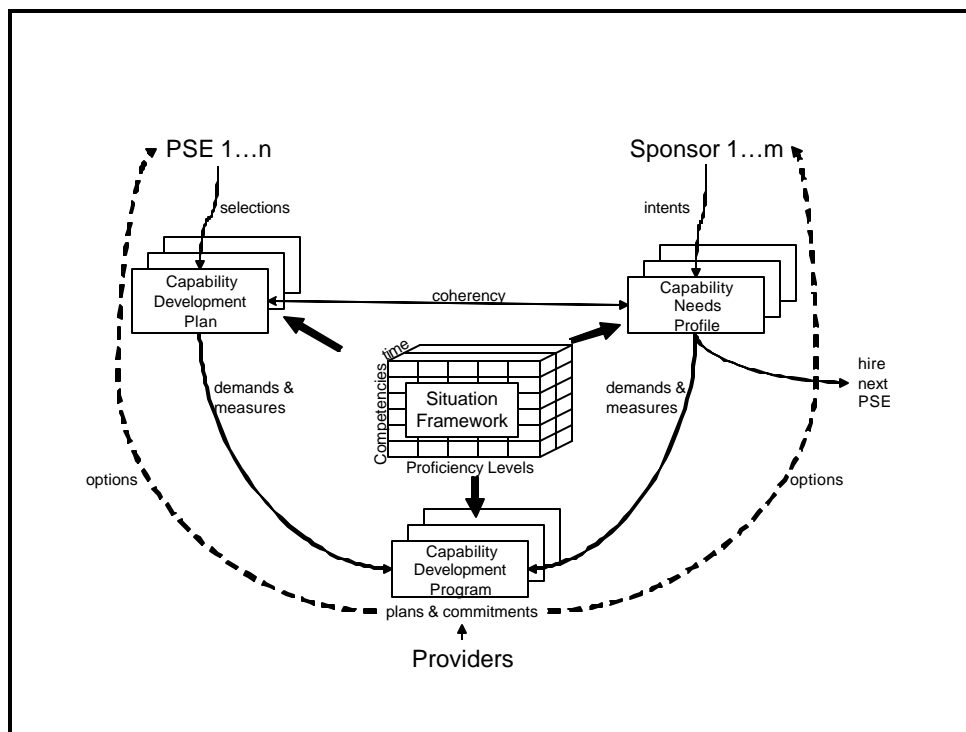
**Example Competencies:** Because a ConOps should not specify content, structure or process of the system being sought it is inappropriate to specify Competencies and Proficiency Levels herein. Other efforts within INCOSE are addressing a taxonomy of competencies and we expect such taxonomy to be compatible with the ConOps. Meanwhile, if the reader wants a clearer understanding of example competencies such a list is presented in Appendix 4.

**Proficiency Level** - an indicator of value-adding potential. The degree to which each participant can apply SE competencies.

**Example Proficiency Levels:** Specifying proficiency levels is similarly beyond the scope of the ConOps but for reference we expect the levels to be something like (descending levels of proficiency):

- SE Fellow
- SE Coach/Mentor
- SE Master
- SE Practitioner
- SE Apprentice
- SE Intern

**Situation Framework:** This suggests that a three axis Competency, Proficiency, Time (CPT) coordinate system will provide an appropriate framework in which the participants can locate themselves and estimate the probable effects of transition choices. Such a framework and its use is illustrated Figure 4.



**Figure 4. A Unifying Framework**

## 7.1. Estimating Current Situations

Each PSE will be located at specific coordinates in this framework and could express desires to target new coordinates. Each PSE's current location will be estimated by means of self-assessment, employer assessments and provider assessments.

A PSE Situation Assessment instrument will be needed and may be based on the INCOSE Taxonomy of SE Competencies or the INCOSE SE Certification instrument or other appropriate schema.

Each PSE's learning potential could be assessed using instruments [Hermann 97], intuition and other means. This would indicate the locus of possible future locations for each PSE and the relative cost and risk of achieving new locations.

Sponsors/Employers would express their current and future needs profiles in terms of the numbers of staff required at each CPT cell. These estimates could be made by incumbent PSE's, associates, prospective PSE's, Providers and "maturity assessment services." Each employer's current profile is thus estimated for each CP cell. In addition, estimates will be made for factors related to PSE effectiveness, such as standards, paradigms, culture, risk preferences, SE make vs. buy proclivity, etc. Also, estimates will be made on the relevance (interrelationship) of these to PSE effectiveness.

Providers will register their capacity at each CPT location, describe the prerequisites as constraints and state their collaboration coefficients with respect to other providers at the cell level. Each Provider's profile of CPT offerings and MOE will be estimated by self-assessment, cross-provider assessments and PSE's (past clients, prospective clients and clients who opted for other providers) as well as assessments by employers.

PSE's and employers focus on "the ends" that is, current and future states of being (CPT locations). In contrast, the providers focus on "the means" that is, state transitions which comprise the value-adding process that facilitates and encourages PSE's and employers to invest in moving from a current competency-proficiency state to a new competency-proficiency state.

Estimates of provider's locations are not limited to the enterprise level of granularity. For instance, the SE specific competencies-proficiencies of provider Principals are important, also, because older and/or more advanced PSE's learn more, faster from those they respect as having "been there, done that." Also PSE's, especially younger ones, seem to learn faster from those who can affect their careers directly. This is another reason why *in situ* can be a powerful subsystem in the SEEC.

Note that a new estimate must be made whenever any participant situation changes.

## 7.2. Choice Making

The respective parties will make choices about which transition actions to undertake. These decisions can be made by estimating the future expected value of each decision and then comparing alternatives and making choices.

### Quantifying the Value-adding Coefficients

Each PSE would estimate the marginal value coefficients expected from alternative job offerings and SEEC providers. Likewise, each employer would estimate a marginal value coefficient for each PSE's enhanced competency development. Finally, each provider would estimate a marginal value for each candidate PSE and each employer relationship.

Organizational inertia must be factored in because it will be a significant deflator of net future value. We estimate inertia of the participants as (in descending order of change proficiency):

- PSE
- Employer Small
- Employer Large
- Provider in situ
- Provider commercial
- Professional Society
- Standards body
- Provider - institution

#### Quantifying the Synergy Coefficients

Because this is a multi-party game each selection is likely to influence the estimate of future expected value on other alternatives. Accordingly, it is necessary to use synergy coefficients between the choices (that is, CPT cells to respective parties and respective parties to respective parties.)

#### Estimating the Net Future Value of Alternatives

The concept described herein supports local decisions but recognizes that each local decision can propagate to global outcomes

The old General's admonition that the winner is the one who comes to battle "the fustest with the mostest" notwithstanding, the SE community and their customers may not be playing in a zero-sum game. Rather, a better metaphor for the system we are seeking may be 'the community caretaking of a common good.'

#### Information Access

Estimates of coupling coefficients may be accomplished periodically, episodically and/or continuously. Regardless, the goal is adequate, accurate and timely data and updates must not be delayed for "control" purposes by any participants.

That all participants must have access to adequate, accurate and timely data is probably obvious but must be stated for completeness. This does not mean that everyone must have the authorization to see all assessments. Privacy and Intellectual Property rights can be honored by allowing for negotiated access. In fact, one participant's refusal to grant access to another participant can be a very informative act,

#### Decision aids

Because of the frequency and implicitness of the choice-making we suggest that the technology of software agents be evaluated for this purpose.

#### **SE Value Web Emergence**

Given the expected volume and interaction of choices the whole system may or may not exhibit any sign of stability. Whether stability emerges is not so much a function of competencies and proficiencies but whether the participants are mutually informed [Axelrod 97] and whether they choose to

- a) compete because they assume a declining returns situation or choose
- b) to co-align because they assume an increasing returns situation [Arthur 90].

Although the majority of current literature on collaboration stresses that the key factor is mutual trust, [Axelrod 97] has shown that members of a group tend toward community norms when they know that detection and punishment are likely. The necessary and sufficient conditions for co-aligning subsystems

amounts to establishing complete and coherent goals for the system and allocating appropriate subsets to respective subsystems as described in [Wymore 97].

It is important to note that a professional association such as INCOSE, in its role as an SEEC subsystem, can be influential in encouraging co-alignment by educating INCOSE constituents on the value of co-alignment. For example, [King] fostered increased dedication to co-alignment by helping member executives and managers experience a model and simulation that demonstrates the value of various levels of collaboration.

## 8. Conclusions

This paper described how those involved in performing systems engineering can go about improving Systems Engineering through a Systems Engineering Education Community (SEEC). An SEEC is envisioned as the vehicle for competency growth by practitioners of systems engineering. Accordingly, an SEEC is both the knowledge source and the learning environment for all of the systems engineering community. Also, an SEEC is envisioned as the vehicle for measuring, quantitatively, both the supply and demand sides of the SE learning community and for managing the data base so generated. Further, the SEEC should be a resource for helping all members of the community make choices about the content, structure, utilization and outcomes of an SEEC.

This paper describes how those involved in performing systems engineering can go about improving Systems Engineering through a Systems Engineering Education Community (SEEC).

An SEEC is envisioned as the vehicle for competency and proficiency growth by all practitioners of systems engineering.

An SEEC can be initialized by transforming the current panoply of SE education environments into a mutually collaborative system that evolves in concert with market needs and education technology opportunities.

When functioning fully and seamlessly an SEEC will generate a sufficient flow of capable system engineering practitioners better, faster and cheaper than is being experienced today and will contain the intelligence to adapt community capabilities and relationships to the on-going, chaotic environment.

The key to such collaboration and purposeful evolution is a community-wide, planning and control system. Because of the dynamics involved the planning and control system is expected to be a complex, adaptive system with a heterarchical architecture. The purpose of this paper is to present a concept of operations for this community and its planning and control system.

The activity of systems engineering (SE) adds value both to a systems design project and to resulting system produced by the project. Although the SE activity adds value in a variety of ways we believe that the majority of contribution is attributable to three main ways. SE

a) establishes system ontology,

b) images both the problem system and solution system and

c) converges risk and creativity to closure. The marginal utility of SE is improved, barring severely constraining factors, by increasing the competencies and proficiency levels of practitioners of SE who are the carriers of SE value to stakeholders. Similarly, the marginal utility of SE practitioners is improved through incrementally experiencing the SEEC learning environment.

The best SEEC is the one that produces a stream of the appropriate mix of practitioners for forthcoming projects and systems at minimum cost and cycle time. Accordingly, the SEEC is always changing -- continuously evolving in subject matter, learning styles, capacity and deployment patterns.

An SEEC serves three types of stakeholders:

- 1) SE practitioners who perform in system development projects,
- 2) SE practitioners who manage SE project teams and SE organizations, and
- 3) SE practitioners who act as principals, e.g. professors and teachers, in an SEEC. Thus an SEEC serves a tripartite improvement process that must be simultaneous and distributed.

Improvement of an SEEC can be accomplished by the familiar [Shewart] PDCA cycle, viz;

**Plan** -- Collectively assess the current situation and forecast the next (time period) objectives,

**Do** -- Prepare the SEEC for delivering the next educational experiences and operate the SEEC on behalf of the practitioners in transit through the SEEC,

**Check** -- Evaluate the degree of achievement of the various goals,

**Adjust** -- Discern the root causes of variances and react to improve conformance to plan.

Because SE is learned in a variety of settings far beyond a typical classroom and because the learning is about the managing and mentoring of SE as well as the doing of SE, the SEEC must offer a heterarchical system for the aforementioned quantification and choice making and for fostering an SE community.

The tripartite SE community needs a rating system that;

- is rooted in customer value,
- has the acuity to assess both actual performance and performance improvement potential of contemplated changes.
- is buffered against erroneous knowledge such as subjective or destructive judgments.

SE practitioner learning environments circa 1999 are unacceptably ineffective. We estimate that cycle times must be reduced three fold and learning extent (span of subject matter X degree of application) must be expanded nine fold.

Our initial estimates of priority must be validated by further surveys during the SEEC design phase but currently indicate that the least prepared SE practitioners are the managers of project PSE's or more precisely, those who control the project work environments and project priorities.

Of second concern are the principals in education organizations, many of whom do not have sufficient actual experience as PSE's to be effective in imparting the SE BoK to adult PSE's.

Commanding third priority are the SE practitioners on projects.

The overall SEEC mission is not world-class SE. The SEEC mission is to create PSE's who are world-class, themselves, and who become continuous learning environments regarding systems thinking,

design/architecting and engineering and system adaptation. To paraphrase a recent political campaign slogan, "It is the community, stupid."

Beyond the initial stages of PSE competency the issue is not so much about What must be learned as about How learning situations must be arranged and created so that "learning to learn" comes to the forefront.

The SEEC notion clearly invites a perspective shift from "the education institution" to "the education experience."

This does not imply in any way that educational institutions are irrelevant. On the contrary, the need for world-class PSE's places a great challenge on such institutions to improve and expand. But it does call for understanding that the educational institutions alone cannot create the spectrum of learning environments required by aspiring PSE's.

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## Appendix A

### A Comparison of Alternative Assessment Systems

**Alternative Assessment Systems:** Employers, Sponsors and Providers must use a consistent system for making assessments. To our knowledge none exists that serve all three purposes. Several of the more popular capability assessment systems have been evaluated relative to this operational need. Six are presented below. The rating system criteria we derived from the situation described in the foregoing sections is shown in Table A-1. Because the focus must be on Results, a Crosby-like rating system is preferable. The EFQM system is considered next best.

**Table A-1. Assessment System Selection Criteria**

Proven Alternatives Exist				
Approach	Locus of	Focus	Mode of	Metric
Champion	Experts	is on	Control	
Crosby	In-Out	R + P*	Systemic	Scalar
EFQM	In-Out	P + R*	Systemic	Rank
Demming	Out-In	Process	Systemic	Rank
ISO 9000	In-out	Process	Embedded	Rank
Baldrige	Out-In	P + R*	Oversight	Rank
EIA 731	Out	Process	Oversight	Rank

\* R = Results, P = Process

#### Review of Popular Assessment Schemes

**Crosby Quality College:** Presumes that the people most capable of improving the system are inside the system provided that they objectively look outside the system for customer requirements. The focus is primarily on results and shifts to process only to correct unacceptable results. Seeks a systemic form of control which is the most effective and efficient form. All assessments are accomplished by incumbents using a quantitative, continuous scale that avoids a culture of 'good enough' In favor of one that seeks 'ever better.' The Crosby approach avoids benchmarks and Best Practices and contains no inertia due to external "standards." The improvement schema is: Identify Customers, Document Requirements, Measure Cost of Quality, Maintain Graph of Price of Non-Conformance™ visible to all participants, Staff and empower Quality Improvement Teams, and focus on and pursue continual improvement of the Price of Non-Conformance.

**EFQM:** <http://www.efqm.org/>: The European Foundation for Quality Management, EFQM, model and assessment method seems to be a version of the Baldrige Award criteria (see below) with more emphasis on Results than Process. Also allows customization by internal experts. Uses only an ordinal ranking scheme.

**Demming Prize:** Presumes the experts are outside the system and the role of the system operators is to adhere to the concepts and rules of the experts. It is process focused in that high scores can be achieved by organizations that follow process even if not producing exemplary results. Seeks systemic control by emphasizing the inculcation of proper process in every participant.

**ISO 9000:** Presumes the experts are within the system but that the system is essentially a trusted subsystem. It focuses on process and emphasizes conformance due to the trusted subsystem viewpoint. It is prejudicial regarding a preferred control scheme because it awards points for embedded control in which there are objective inspectors throughout the organization continuously observing the process and documenting variances. Guidelines are sparse. Conformance to process is rewarded with high rankings but process results (the product) are not considered

**Baldrige Award:** In addition to the well known Baldrige Award for business the Baldrige National Quality Program has established the 1999 Criteria for Performance Excellence in Education, 1999 Education Criteria.

Interestingly, 45% of the attainable score is on Results as contrasted to 10% on Process Management. However, similar to the criteria for businesses the Education Criteria are established by experts outside the system being evaluated. Although emphasizing both process and results it permits an oversight mode of control which is less intensive and has less acuity than embedded and even less than systemic.

It should be noted that Phil Crosby, and other quality guru's have gone on record in opposition to the Baldrige approach. In essence they feel it drives users toward false optima.<sup>1</sup>

**EAI 731:** Presumes the experts are outside the system and the role of the system operators is to adhere to the concepts and rules of the experts. Allows tailoring (if done to tailoring standards) for specific program needs but Tailoring.

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<sup>1</sup> Dr. Deming's principle objection to the Baldrige award [was] that the award articulated no philosophy of management and hence would lead some to copy others without understanding.  
<http://deming.ces.clemson.edu/pub/den/archive/2000.04/msg00046.html>

1999 Categories/Items	Point Values
<b>1. Leadership</b>	<b>110</b>
1.1 Leadership Sys tem	80
1.2 Public Responsibility and Citizenship	30
<b>2. Strategic Planning</b>	<b>80</b>
2.1 Strategy Development Process	40
2.2 School Strategy	40
<b>3. Student and Stakeholder Focus</b>	<b>80</b>
3.1 Knowledge of Student Needs/Expectations	40
3.2 Student and Stakeholder Satisfaction and Relationship Enhancement	40
<b>4. Information and Analysis</b>	<b>80</b>
4.1 Selection/Use of Information and Data	25
4.2 Selection/Use of Comparative Data	15
4.3 Analysis/Review of School Performance	40
<b>5. Faculty and Staff Focus</b>	<b>100</b>
5.1 Work Systems	40
5.2 Faculty/Staff Ed, Trng, and Devel	30
5.3 Faculty/Staff Well-Being and Satisfctn	30
<b>6. Educational and Support Process Management</b>	<b>100</b>
6.1 Education Design and Delivery	60
6.2 Education Support Processes	40
<b>7. School Performance Results</b>	<b>450</b>
7.1 Student Performance Results	150
7.2 Student/Stakeholder Satisfctn Results	100
7.3 Faculty and Staff Results	100
7.4 School-Specific Results	100
<b>TOTAL POINTS</b>	<b>1000</b>

[http://www.quality.nist.gov/docs/99\\_crit/99crit.htm#education](http://www.quality.nist.gov/docs/99_crit/99crit.htm#education).

Seeks periodic, oversight-style control and presumes that the past performance of an organization is a predictor of a future project team's capability, a highly suspect assumption. Uses a six-level ordinal scale for characterizing capability maturity of an organization. As the basis for assessment uses qualitative differences in behavior relative to pre-specified Categories, Focus Areas, Themes, Specific Practices and Generic Attributes. Quality is not defined and pursuit of quality is on programmatic aspects and not on the resulting system. Focuses Risk Management on program aspects and not on the resulting system. Complexity, a major consideration in SE, is mentioned at Level 0 and Level 5 but not elsewhere and is not a formal factor. Has not quantitatively demonstrated that its ordinal scale correlates with measures of project nor system effectiveness. Finally, assuming an organization would want to evolve up the levels, it is not clear what organizational change theory or model the authors assumed when assigning the pattern of practices to the respective levels.

## Appendix B

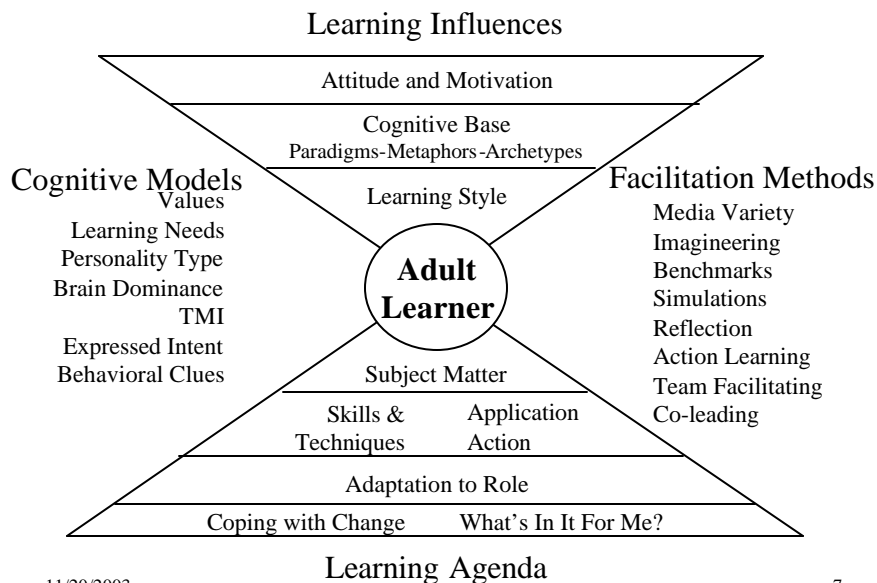
### PSE's As Adult Learners

The user in the SEEC scenario is the individual PSE, whether he/she performs in Projects, in employer/client management or as a principal in one or more of the SEEC subsystems. For the purposes of the SEEC ConOps it is important to understand the PSE as an adult learner. This Note presents an adult learner model for perspective on the variety that the SEEC must offer.

Obviously, the population of PSE's will be far from homogeneous. However, some invariants are expected. First, PSE's will be primarily adults, most having earned one or more college degrees but not necessarily in engineering disciplines. Secondly, each PSE will tend to be a generalist, have a tolerance for ambiguity and an ability to exhibit both divergent and convergent thinking styles. Thirdly, the PSE population, although representing perhaps only about 4% of the spectrum of personality types, will still represent distinctly different learning styles. Consequently, an SEEC must offer multifaceted learning environments even for the same subject matter.

As illustrated in Figure B-1. Adult Learner Model, several factors must be brought together and harmonized if the SEEC is to serve the SE community.

### Adult Learner As System



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**Figure B-1. Adult Learner Model**

Four major factors influence the PSE's likelihood of learning, retaining and applying new competencies or levels of proficiency. The first two, Learning Influences and Learning Agenda are directly concerned with content whereas the second two, Cognition Models and Facilitation Methods are concerned with the learning environment.

**Learning Influences** include the Attitude and Motivation of the PSE regarding the learning opportunity. Also included is the Cognitive Base of the specific PSE in terms of specific domain knowledge and of the paradigms, metaphors and archetypes that open paths to new cognitions. Finally, is Learning Style. Each person has a distinct learning preference that significantly influences their intake, retention and application characteristics. According to [Isachsen] as summarized in Table B-1, there are distinct relationships between a person's the Meyer-Briggs Type Indicator (MTBI) and his/her preferred style of learning.

**Table B-1. The Learning Styles associated with MBTI types**  
**Meyer-Briggs Type Indicator**

Introvert -- **Extrovert**  
Thinking -- **Feeling**

**IN**tuitive -- **S**ensing  
**P**erceiving -- **J**udging

<b>INFJ</b> Prophet 1%	<b>INFP</b> Hygienist 1%	<b>ISTJ</b> Inspector 6%	<b>ISFJ</b> Protector 6%
<b>ENFJ</b> Pedagogue 5%	<b>ENFP</b> Apocalyptic 5%	<b>ESTJ</b> Supervisor 13%	<b>ESFJ</b> Provider 13%
<b>ENTJ</b> Field Marshall 5%	<b>ENTP</b> Inventor 5%	<b>ISTP</b> Artificer 7%	<b>ISFP</b> Composer 5%
<b>INTJ</b> Strategist 1%	<b>INTP</b> Definer 1%	<b>ESTP</b> Promoter 13%	<b>ESFP</b> Performer 13%

**Learning Preferences**  
*(overlay on table above)*

<p>personal learning, disinterest synthesizer in rules &amp; details</p> <p>global, abstract, interaction, dialog, written word, relates to teacher; else blocks</p>	<p>work books, rote, memorization, linear, visual, difficulty learning abstractions</p>
<p>conceptualizing, abstracting, categorizing, works alone fears peers seeing failures</p>	<p>observational, hands-on, projects concrete, want results group interaction</p>

Adapted from: *Working Together*, Isachsen, O. and Berens, L., 1988, Newworld Press

In Table B-1 the upper matrix shows the sixteen categories of the MTBI instrument are shown. The numerals indicate the percentage of the population represented by each type. The lower matrix shows the learning styles associated with the MTBI types. Note the significant difference between the lower left quadrant wherein NT types want to work alone and fear peers seeing failures as contrasted to the lower right quadrant wherein the TP and FP types prefer group interaction and want to try things to see whether they will work. [Rechtin] notes that most system architects are NT types. Little wonder they do not collaborate well with the design and build crowd of TP and FP persuasion.

Alternatively to Isachsen's model [Herrman] has pointed out that learning styles differ according to his Brain Dominance typology. Similarly, the Theory of Multiple Intelligences (TMI) can apply.

**Learning Agenda** includes subject matter regarding not only systems and engineering disciplines but also regarding SE process and context. The learning objective is two fold. One concerns learning techniques and skills and the other concerns learning to apply them. Further, because he/she is now different than before transiting the SEEC the PSE must learn to handle the cultural and political aspects of his/her new techniques, skills and actions. Further each PSE must learn about Coping with Change because each will be undergoing subsequent change and will be causing others to experience change. Finally, the content of the learning must deal with WIFM, What's In It For Me? Unless a PSE becomes convinced that practicing the techniques, skills and application in the real world is going to be personally beneficial, the learning process is not going to add much value.

**Cognitive Model** assists both the PSE and the provider in locating the PSEs' situation in terms of personal values, learning styles and behavioral clues that will inevitably be exhibited during the learning session.

**Facilitation Methods** repertoire reflects a variety of teaching, mentoring, coaching methods that every provider should have or be associated with. These are especially important for the *in situ* subsystem. Consider, for example, the learning sessions described by [Schon] a frequent co-author with Chris Argyris on organizational learning.

## Appendix C

### Gradients of PSE Value

In addition to personal competencies and proficiency levels several factors influence the combined value that any two or more PSEs' add in a project. These are the gradients of the value-add factors. Some gradients are synergistic whereas others tend to degrade the value delivered.

1. **Fluency of project members** -- if the project members are not previously aware of and fluent in the language of SE then even the best SE efforts and artifacts can be for naught.
2. **Incomplete artifacts** -- an incomplete set of SE artifacts as well as discrepancies among the SE artifacts will result in an insufficient basis for system development and will give rise to "local invention" that, although well meaning, may not be consistent with the balance of the artifacts.
3. **Due diligence** -- unless due diligence is exercised over the balance of the project after the SE artifacts are produced, the intent of the SE artifacts will be compromised. Due diligence does not mean 'suppress innovation' but it does mean 'conduct a responsive and accurate change approval process.'
4. **Number of PSE's** -- increasing the number of PSE's on a project may increase the value adding potential. However, both productivity and innovation will suffer unless the SE work is parsed for teams of four or fewer PSE's.
5. **Competencies repertoire** - the more competencies possessed by an individual PSE the fewer PSE's are needed on a given project. The goal may seem to be "one each of the smartest PSE in the world." However, the bandwidth of the project, especially an Integrated Product and Process Development (IPPD) project may require more PSE's. [Ring 94]
6. **Proficiency levels** in the respective competencies - although it may seem that each project should have the best available talent an expert PSE does not necessarily produce the best outcome. Assigning a highly accomplished PSE to a project that is not challenging may be good for the project but not for the PSE because an episode of non-challenging work diminishes that PSE's rate of learning thus the ability to add value on a subsequent project. Also, to the degree that the price of a PSE is consistent with competency-proficiency, the underchallenging project has to pay too much for the overqualified PSE.
7. **Interpersonal styles**- a PSE with stunted interpersonal style will diminish the productivity and innovation of others on the project -- by up to ten fold. [Livingston]
8. **Learning styles**- because PSE's have different learning styles [Isachsen] [Hermann] one PSE may get more value out of learning a topic in a classic educational institution while another PSE may get more value out of learning the same topic in a commercial provider environment while yet another PSE may benefit from learning the same topic on the job.
9. **'Plic' of Problem** -- (from the Latin, plic, meaning to fold indiscriminately) the more complicated the problem the more competency and proficiency is required to understand it and conceive a solution system.

10. **Consensus of Beneficiaries** - projects in which a variety of beneficiaries have conflicting agendas and objectives will demand more competent-proficient PSE's especially those with problem definition competencies.
11. **'Plex' of Solution** – (from the Latin, plex, meaning to arrange in a pattern) more complex solutions require higher order systems which generally require higher competency and proficiency PSE's. PSE's turn “plic” into “plex” then leverage plex to advantage.
12. **Rate of change of Problem space** - the faster the problem space changes the more iterations are required in the system design or even the system thinking aspects of the SE project.
13. **Rate of change of Beneficiaries' Objectives**- even if the Problem space stays stable the faster beneficiary objectives change the more iterations are required in the system identification and design or even the system thinking aspects of the SE project.

## Appendix D

### PSE Span of Competencies

Although the focus is typically on PSE's who staff projects this ConOps applies to PSE's who perform as managers in employer/client organizations and to principals in provider organizations. All must be PSE's and the SEEC must respond to the span of competencies required by all.

We list examples of these in the interest of a more clear and useful ConOps. This list is not intended to be comprehensive. It should be replaced with the INCOSE Taxonomy of SE Competencies when such becomes available.

#### Example PSE Competencies

Because a PSE is a system the MOE's, Fit for Purpose, TBO/TCO and Agility apply.

##### **PSE competencies regarding Fit for Purpose include:**

1. Image and Structure the Problem and Solution,
2. Language the Project,
3. Converge creativity and risk to closure,
4. Know system archetypes and principles,
5. Know problem space domain knowledge
6. Know the methods for coping with Risk and Uncertainty."
7. Know how to SE "peopled systems" which include Technical, Cultural and Political interrelationships [Tichy].
8. Be proactive (anticipatory, exploratory behavior which leads to early identification of issues and responses),
9. Be a Reflective Practitioner [Schon] (who learns faster, in situ, than the non-reflective),
10. Be Encouraging and Admonishing (an interpersonal style that generates the maximum level of useful productivity in a workgroup as contrasted to the Anxious and Insincere style or, worse, the Critical and Obstructive style) (4).

##### **PSE competencies regarding Total Benefit of Ownership/Total Cost of Ownership TBO/TCO includes:**

1. (TCO) - Replacement Cost (as determined by market norms, level of competency, rate of knowledge production),
2. (TCO) - Redeployment Cost (as enabled by degree of agility, change proficiency and geographical relocation), and
3. (TCO) - Evolution Cost (or learning power as indicated by quality ethic, propensity for knowledge utilization, and acuity of knowledge identification).
4. (TBO) - Net Effect of SE on Sponsor's System (Fit for Purpose, TBO/TCO of the delivered system, and Agility)
5. (TBO) - Net Effect of SE on Total Project (Return on Resources, Cycle Time and Value Added)
6. (TBO) - Net Effect of SE on SEEC (as a knowledge contributing agent affecting Return on Resources, Cycle Time and Value Added -- for self and others).

### PSE competencies regarding Agility:

1. Apply the "Ten Principles for the Design of Agile Systems." [Dove] Agility is the capability to thrive in an environment of unpredictable change.

### Example Provider Competencies

Because an SEEC is a Project the MOE's Value Added, Cycle Time and Return on Resources apply.

### Provider Competencies Regarding Value Added: Every SEEC subsystems must:

1. Do Knowledge Transfer,
2. Do Knowledge Production (about systems, PSE's and SEEC's),
3. Do Self-assessment (regarding the efficacy of the SEEC),
4. Know how to see the SEEC as a system,
5. Know how to see an Adult Learner as a system,
6. Be a robust learning environment,
7. Be collaborative (across subsystems),
8. Be Goal-seeking (because the demands will be continually changing and there will never be enough resources when needed.)
9. Be practicing PSE's at high levels of demonstrated proficiency:
  - an SEEC leader, regardless of current home subsystem, must be an on-going SE practitioner who is experiencing high scores in Design Reviews and loud applause from sponsors of the systems he/she has fostered. For example, at Julliard the leader must be an accomplished musician, at the Bauhaus the leader must be an accomplished architect.
  - the SEEC leader can articulate the relationship between SEEC capability and PSE competency.
  - an SEEC leader cannot operate *in vacuo* because no one subsystem can accommodate more than a minor percentage of the PSE's learning experience. Further, the PSE should not have to carry to burden of the integrator -- the SEEC subsystems should achieve integration in advance of the PSE's traverse.
  - Consequently, each SEEC leader be a highly competent PSE which means being a continuously active PSE in a broad spectrum of problem space-solution space couplets.

### Provider Competencies Regarding Cycle Time:

To minimize the Cycle Time required by SEEC subsystems while they Maximize Value Added each subsystem must;

1. Customize the learning programme to each PSE,
2. Measure the Cycle Time
3. Accomplish Self-assessments.
4. Know the TBO being achieved,
5. Know the tradeoffs among learning, retention and application (so that the learning experience can be customized),
6. See the PSE as a system
7. Deliver a systemic learning process rather than "applying the patch"
8. Collaborate with other subsystems,
9. Use PSE time and SEEC resources efficiently
10. Sustain agility.

### **Provider Competencies Regarding Maximize Return on Resources both consumed and monopolized**

1. Do Resource Allocation and Scheduling (which implies that it must be able to construct a demand list and response surface), measure Return (so that it can know how it is doing) and Align Resource Mix (so that it can manage the tradeoff gradients between desired resources and available resources vs. time).
2. Measure TBO for each PSE, and how far from the goal the PSE is at any point in time. Know future demand by its planned constituency so that it is not trying to evolve a PSE for which there is no demand.
3. Maintain collaborative options so one subsystem can call on another for an assist.
4. Be Collaborative, Agile and Change Proficient just as a PSE must be.

### **Example Employer Competencies**

Employers have a double role. In one role they are Providers of in situ learning environments and in this regard their competencies have been covered above under Provider competencies. In their other role they are sponsors-- not of systems but of projects and specifically the work climate and culture extant during the project. Accordingly, example competencies are:

1. To adopt to the methods, techniques and tools of the evolved PSE's
2. To adapt their associated practices; Project Management, Development and Test engineering, manufacturing engineering, accounting, marketing, etc.
3. To acknowledge the increased complexity and adaptability required of solution systems and the resultant standards that they adopt.
4. To understand SE and the SEEC
5. To understand their respective possibilities that are opened up by competency development.