AC 2012-3957: A PROSPECTUS FOR THE CERTIFICATION OF SYSTEMS ENGINEERING DEGREE PROGRAMS

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A Prospectus for the Certification of Systems Engineering Degree Programs

Abstract

Because of its relevance to the whole of engineering education, the ASEE Systems Engineering Division (ASEE-SED) has a unique opportunity to serve as a forum to consider the development and quality aspects of degree programs that are named Systems Engineering (SE). This paper (a prospectus) conjectures that it may be necessary to provide worldwide academic certification of SE degree programs by participating in and going beyond accreditation as offered through the Accreditation Board for Engineering and Technology (ABET).

Although the possibility of degree program certification is the main focus of this prospectus, certification is not the only topic. This paper suggests that program certification may be one means to overcome existing impediments to advancing the quality dimensions of Systems Engineering degree programs. These impediments are addressed by proposing some criteria agreements and collaborative arrangements within the engineering profession. Included are definitional, organizational, jurisdictional, and procedural enablers essential to collaboration among the engineering domains that constitute ASEE. These are the same bodies that participate in the accreditation of engineering programs through ABET.

I. Introduction and Prospectus Raison D'etre

Private and public enterprises worldwide are keenly interested in innovations within engineering education that would leverage the benefits of systems thinking inherent within the process and practice of Systems Engineering. Accordingly, the overarching raison d'etre for developing and offering this prospectus as an ASEE-SED paper are the existing Systems Engineering degree programs (without modifiers) for which there is not yet a designated ABET lead society.

Although the certification of System Engineering degree programs is given as the title of this prospectus, program certification is not suggested as the preferred end. It is offered to bring focus and needed study to quality assurance within the SE undergraduate degree sector and the rapidly growing SE graduate degree sector, defined in Section III as Systems Centric SE. Domain Centric SE, also defined in Section III, is of secondary concern, because this sector is provided regular oversight by ABET through the cognizant participating bodies.

To achieve the purpose of this prospectus, a number of relevant issues are introduced and discussed to provide context and insight. This is needed to provide stakeholders' common understanding of the scope of the oversight deficiency, a clear description of the affected degree program sectors, and possible opportunities for collaboration across disciplinary boundaries. Some of these issues were addressed with tabulated data two years ago in the paper entitled *"Systems Engineering: Its Emerging Academic and Professional Attributes"* presented at the 2010 Annual Conference and Convention of ASEE.[1]

Material in the cited ASEE paper of 2010 is extended herein by addressing several topics germane to the purpose of this prospectus. These topics are abstracted below, together with a compact statement of the reason for giving them special visibility:

1. A definition and description of Systems Engineering - Any reference to SE should be accompanied with some explanation about what the author believes SE to be. This is essential for effective communication due to difficulties arising from the numerous and varied views and interdisciplinary nature of the field.
2. An analysis of Systems Engineering degree programs - Degree programs in SE occur at all levels and in various configurations. A discussion about SE degrees should be clear as to the target sector involved.
3. Systems Engineering degree program accreditation - Institutional and programmatic accreditation should be contrasted with the current status of SE accreditation within the current ABET criteria and approach.
4. Accreditation, certification, and licensure - Each of these related quality enablers should be discussed to facilitate a robust basis for examining and evaluating the applicability and usefulness of each one in the SE context.
5. Need for SE academic program certification - The need and potential benefit of SE program certification is a prerequisite to giving it a due hearing. The source of the need should be made visible so that its worth can be assessed.
6. An emerging opportunity for focus on quality - Currently under collaborative development is an initiative entitled GRCSE (Graduate Reference Curriculum for Systems Engineering) that provides a unique opportunity for focusing on program quality.
7. Status and maturity assessments - The role of academic program certification in advancing the stature and maturity of SE should be considered in light of private and public sector requirements for the 21st century.[2]

The seven topics above serve to introduce and give a rationale for each major section of this paper. Their aim is to justify examination of the question of SE degree program certification and to showcase the degree to which a cooperative effort among the engineering societies would serve to benefit the engineering profession as a whole.

II. Systems Engineering Defined and Described

To this day, there is no commonly accepted definition of Systems Engineering found in the literature.[3] "Systems Engineering is an amorphous, slippery subject that does not lend itself to such formal, didactic treatment. One does much better with a broader, more loose-jointed approach. Some writers have, in fact, sidestepped the issue by saying that Systems Engineering is what systems engineers do." [4]

Systems Engineering Defined. Definitions of Systems Engineering and the systems approach are usually based on the background and experience of the individual or performing organization. The variations are evident from five definitions with cited sources found in the textbook *Systems Engineering and Analysis*.[5]

Although SE definitions vary, there are many common threads. Basically, Systems Engineering is holistic engineering with special areas of emphasis. Some of these are: a *top-down* approach; a *life-cycle* orientation; a more complete early effort regarding the *definition of system functions*, relating functions through *requirements* to design criteria, followed by an effort to ensure the *effectiveness* of early decision making within the design process on downstream outcomes; and an *interdisciplinary* or team approach applied throughout the process.

Systems Engineering is not a traditional engineering discipline or domain in the same sense as civil engineering, electrical engineering, industrial engineering, mechanical engineering, manufacturing engineering, reliability engineering, or any of the other engineering disciplines and domains. It should not be organized in a similar manner, nor does the implementation of Systems Engineering or its methods require extensive organizational resources. But, for best results, a well-planned and *disciplined approach* should be followed.

Systems Engineering Described. Systems Engineering may be described as a technologically based interdisciplinary process for bringing human-made systems and their products (technical entities) into being. While the main focus is nominally on the entities themselves, Systems Engineering offers an improved strategy. Systems Engineering is inherently oriented toward "thinking about the end before the beginning". Conceptually sound systems engineering derives from *what the system is intended to do* before determining *what the system is*, with form following function.

The focus of Systems Engineering is most effective when based on essential design dependent parameters, recognizing the concurrent life-cycle factors of production, support, maintenance, sustainability, phase-out, and disposal. It invokes integrating synthesis, analysis, and evaluation. These considerations are germane to system and product design when imbedded within the systems engineering process. The overarching purpose of SE is to bring cost-effective systems, products, and services (the human-made world) into being.

Instead of offering systems or system elements and products per se, Systems Engineering focuses on designing, delivering, and sustaining *functionality, a capability,* or a *solution.* This strategic thinking is now being considered by forward-looking enterprises in both the private and public sectors. It is applicable to most types of technical systems, encompassing the human activity domains of communication, construction, defense, education, healthcare, manufacturing, transportation, and others.

III. Systems Engineering Degree Programs

Over time, infusion of systems thinking into engineering curricula has been formalized in discrete courses, but Systems Engineering means different things to different people. This is especially true for the meaning imparted to SE degree programs by academic institutions. A degree program designated SE at one institution may not be the same as a degree program with the same designation at another. In considering the attributes of degree programs called Systems Engineering (whether they are Systems Centric or Domain Centric) one should go directly to the published curriculum to examine course content. At issue here is the advertising related question of "*What's in a Name*?

In 2009 it was determined that 80 institutions in the United States offer 165 undergraduate and graduate degree programs involving Systems Engineering. This count is an increase of 5 institutions and an increase of 35 SE degree programs since a similar study conducted in 2005.[6]

Systems Centric Systems Engineering (SCSE) Programs. Basic and advanced level programs leading to a bachelors or higher degree in Systems Engineering comprise a distinct category with a discipline-like focus. Included herein are only those degree programs where the concentration is designated Systems Engineering; where SE is the intended major area of study.

There are 37 institutions that offer 56 degree programs in the SCSE category. There was no increase in the number of undergraduate programs, but graduate programs increased by 8 over the five-year study period (2004-09). The count by degree program level is given in Table 1.

Table 1. Systems Centric Systems Engineering (SCSE) Program Counts

	BS		MS		PhD	
Program count	11	+	31	+	14	Total = 56

Domain Centric Systems Engineering (DCSE) Programs. Basic and advanced level programs leading to a bachelors or higher degrees with the major designated as X Systems Engineering, Systems and X Engineering, etc. are designated Domain Centric SE. Included in this category are those degree programs naming Systems Engineering within a parent engineering domain.

On the basis of program names alone, there were 48 institutions with 82 DCSE degree programs in 2004. Now 52 institutions (9 of these duplicate institutions in the SCSE category) offer 109 DCSE programs across several engineering domains. These are given in Table 2.

Table 2. Domain Centric Systems Engineering (DCSE) Program Counts

	BS	MS	PhD	Total
SE with Biological Engineering	18	10	6	34
SE with Computer Engineering	7	5	3	15
SE with Industrial Engineering	17	17	13	47
SE with Management Engineering	1	2	0	3
SE with Manufacturing Engineering	1	8	1	10
Totals	44	42	23	109

A continuing goal is to integrate Systems Engineering topics into selected courses within the traditional engineering disciplines. Widening the number of disciplines and application areas to which SE may be applied will likely enhance *systems thinking* within more engineering domains.

Organization and Administration of SE Programs. Not all Systems Engineering degree programs are administered through the classical departmental structure of the host institution. One must be aware of the administrative and organizational home for a degree program of interest to fully understand its academic context.

When considering basic and advanced level programs in the SCSE and DCSE categories, focus will be targeted properly by recognizing that Systems Engineering is broad in nature. It should not be viewed in the same context as the traditional engineering disciplines. This notwithstanding, many domains of engineering are seeking a better topical balance by adopting *systems thinking*. This is the primary reason for the rapid growth in the number of engineering academic domains embracing SE topics and projects.

IV. Systems Engineering Degree Program Accreditation

ABET leaves it to the institution to choose the degree level at which it will seek program accreditation; that is, to declare whether the first 'professional' degree for entry into the profession is to be at the basic or the advanced level. However, in 2006, ABET removed the constraint on accreditation at both levels for a singles domain specialty.

Accreditation of SE Programs. Criteria for the accreditation of Systems Engineering programs at the basic level are based upon the published General ABET Criteria for those institutions offering programs at this level. Institutions seeking accreditation for the first professional degree in Systems Engineering at the advanced level must meet the published General ABET Criteria for advanced level programs in addition to the basic level criteria.[7]

It is the policy and practice of most academic institutions to submit only undergraduate programs for ABET accreditation. Thus, the opportunity for professional societies to influence graduate programs through ABET is quite limited. This is thought to be detrimental to the advancement of Systems Engineering because SE rarely builds directly upon an ABET accredited SE undergraduate program in the traditional way.

Omitting SE at the doctoral level, the number of SE programs by category, and the number of ABET accredited programs (noted by **bold type**), are summarized in Table 3. Details regarding ABET programs that are accredited may be found at www.abet.org

Table 3. SE Programs by Category and Degree Level with those Accredited in Bold

SE Category	Number BS/BS	Number MS/MS	Number of Programs	% ABET Accredited
Systems Centric SE	11/**11**	31/**2**	42/**13**	31%
Domain Centric SE	44/**44**	42/**1**	86/**45**	52%
Totals	55/**55**	73/**3**	128/**58**	45%

Fifty five (55) of the 128 degree programs in Systems Centric SE and Domain Centric SE are at the undergraduate level, with all nominally being ABET accredited. This leaves 73 SE programs at the graduate level, only three of which are ABET accredited.

Graduate programs in Systems Centric SE outnumber undergraduate programs by 3 to 1.
And, since only 58 out of the 128 degree programs in SE are accredited, this void is the basis for the suggestion that academic program certification at the graduate level be considered.

The proper absence of an INCOSE lead position for Domain Centric SE programs and absent the willingness of most academic institutions to offer graduate programs for ABET accreditation, leaves only 11 SE Centric undergraduate programs to be influenced by INCOSE. That was the basis for a paper entitled *INCOSE Academic Certification: Participating in and Going Beyond ABET*.[8] The major theme of this paper centers on that same issue, but now includes ASEE - EED as a possible enabler.

Multiple Lead Society Concept. Systems Engineering academic programs have been accredited by ABET for several years without a designated society for leading the accreditation of these programs. Programs with titles that include the term "systems engineering", modified by or joined with another engineering discipline, are evaluated by the criteria of the associated discipline and under the leadership of that discipline's lead society. However, a lead society has not been designated for the accreditation of Systems Engineering programs that do not have modifiers in their title.

To address this situation, a meeting was held in Baltimore on March 21, 2006, hosted by ABET and administratively hosted by SAE International. Its purpose was to discuss the designation of a lead society for the accreditation of programs specific to systems engineering. All ABET member societies and other organizations with an interest in systems engineering accreditation were invited to attend. Participants at the meeting included representatives of ABET and 14 organizations: AAEE, ASABE, ASCE, ASME, CSAB, IEEE, IIE, INCOSE, ISA, NSPE, SAE, SME, and SME-AIME.

The mission of ABET is accomplished through the professional engineering societies serving as participating bodies. After a seven year application and approval process, the International Council on Systems Engineering (INCOSE - www.incose.org) became a participating society in ABET in 2008.[9] Three years later the Systems Engineering Constituent Committee of ASEE gained full Division status.

Accordingly, ABET has adopted a Multiple Lead Society (MLS) approach for accrediting degree programs that are of interest to more than one participating society. Systems Engineering is one of the first programs to come under this approach, the characteristics of which are:

1. The MLS approach applies to SCSE programs, thus encouraging cooperation within SE while avoiding undue competition.
2. INCOSE assumes the nominal obligation to accredit SE degree programs (mostly SCSE) upon university request through ABET.
3. INCOSE has the opportunity to collaborate with those ABET participating societies that incorporate SE topics in their engineering domains of study (ASME, IEEE, IIE, ISA, SAE, SME, and others that may join the MLS cluster for SE).
4. Through participating society status, INCOSE has direct involvement within academia for Systems Centric SE, and indirect influence for Domain Centric SE, all administered within the ABET programmatic accreditation enterprise.
5. At present, there are no program specific criteria for Systems Engineering. The opportunity to collaborate in the development of SE criteria still exists.

The Multiple lead societies fully support the General ABET Criteria as it applies to basic level and to advanced level accreditation, recognizing that the decision to apply for accreditation review at the basic or the advanced level is to be made by the institution. Participating bodies provide the criteria and institutions choose the accreditation level to be requested.

SE Program Specific Criteria. At present, there are no program specific criteria for Systems Engineering. Thus far, SE programs have been accredited by ABET upon request under a special category. Program criteria unique to Systems Engineering will be developed by the group of participating societies for SE under the Multiple Lead Society Concept (see above).

This will be accomplished through the Engineering Accreditation Commission of ABET in due time and approved by the ABET Board when consensus has been reached.

There was an initiative at the academic levels of IIE and INCOSE to collaborate on SE Program Specific Criteria prior to its consideration by the entire SE working group. Your author was asked to provide input. Its content and disposition is described below.

1. Curriculum - The curriculum must prepare graduates to synthesize a system for delivering and sustaining functionality, a capability, or a solution. Included in the curriculum must be instruction and exercises involving system design and analysis, design evaluation and validation, and system development. Systems thinking must be inculcated during all phases of the life cycle, with primary focus on what the system is intended to accomplish.
2. Faculty - Evidence must be provided that the program faculty possesses current capability in the appropriate engineering and supporting disciplines together with professional practice for the engineering of human-made systems in the modern world.

Regrettably, this informal collaboration met with resistance. Word of the informal effort somehow came to the attention of the IIE Board of Trustees and the CIEADH. Unanimous votes were cast by both bodies making it clear that IIE does not favor any consideration of program specific criteria for Systems Engineering. A similar negative vote was generated in 1998 when these bodies of IIE were asked if they would welcome informal discussion about INCOSE applying for participating body status in ABET.

V. Contrasting Accreditation, Certification, and Licensure

Too often there is a lack of definition and clarity in the usage among and between words having to do with the quality and/or merit of academic programs and the graduates therefrom. Since this paper is centered on one of these (certification) and underpinned by another (accreditation), it is appropriate to examine and contrast, to an extent, the meanings as used herein.

Accreditation. In broad terms, accreditation is available at the institutional level and/or at the program level. Inherent therein is a pervasive misunderstanding that accreditation of an academic institution means that the degree programs of that institution are accredited.

It is true that the majority of degree programs within colleges and universities do not have a cognizant accreditation organization and opportunity. It is also true that some degree programs claim to be accredited by virtue of the program being offered within an accredited institution. But this does not have the same operational effect as having program specific oversight as provided by, for example, the Accreditation Board for Engineering and Technology (ABET) serving as their agent.

The Accreditation Board for Engineering and Technology is a federation of societies that accredits academic programs in engineering and related areas of the applied sciences. This is accomplished through four Accreditation Commissions. Unlike bodies that accredit the entire academic institution, ABET focuses on the characteristics of programs and the products of these programs for the purpose of advancing the quality thereof.

Certification. Certification is most often used as an occupational designation to provide confirmation of an individual's *competency* (demonstrated education, experience, and knowledge) in a specified profession or occupational specialty. Certification may also be applied to an academic program, providing a *measure of assurance* about the quality of program graduates. Certification also differs from licensing in that *licenses are permissions* granted by governmental authorities for a person to practice within its jurisdiction.

Certification is a formal process issued by an organization. Certification is normally voluntary. It is neither a barrier nor a gateway to entering employment. However, it is often used as a qualifier in placement within the corporate world.

Professional certification is based on standards, often more advanced or exacting than are established by a profession itself. Certification is a formal process whereby a group of knowledgeable, experienced, and skilled representatives of an organization provides formal recognition that a person has achieved competency in specific areas as demonstrated by education, knowledge, and experience.

Within INCOSE there is the Certified Systems Engineering Professional (CSEP) program offered at three levels; Associate SEP, Certified SEP, and Expert SEP. Similar programs are available within most engineering technical and professional societies. And, like INCOSE, there often exists tension within a society between the academic membership and those from the non-academic sectors regarding the characteristics and value of professional certification.

Licensure. Licensing differs from certification in that licenses are permissions granted by a governmental authority for a person to practice within its regulatory boundaries. Licensing differs from a "certificate" that documents the successful completion of a training or education program. It also differs from certification as described above. Happily, reciprocity of professional registration is granted among most of the states in the United States.

Licensure is usually sought by engineers in those practices that directly impact public health, safety, and welfare with prime examples being civil and environmental engineering. However, a broadened view of the public interest could include Systems Engineering as an important profession for professional registration. The common industrial exemption could be reconsidered for engineers responsible for outcomes regarding the viability of complex and costly human-made systems of today.

Increasingly, progressive employers are encouraging individuals to pursue engineering licensure. Many employers recognize that licensing for engineering professionals not only meets legal requirements, but also ensures that their professionals are prepared to meet national and international standards of engineering practice. Disappointments arising from cost, schedule, and even performance aspects of complex risky technological undertakings in the public interest suggest consideration of licensure as a possible requirement for systems engineers.

VI. Accreditation is Necessary but Not Sufficient

Returning again to certification, but squarely in the context of academic programs. In contrast to certification of individuals as presented in Section V, academic program certification strives to enhance the assurance that program graduates are uniformly of high quality. By improving the process producing graduates through certification, it is conjectured that the product thereof will be of higher quality and capability.

It is argued that Systems Engineering accreditation by ABET is necessary but not sufficient for at least four reasons:

1. Nominally, only undergraduate degree programs are offered by academic institutions for ABET accreditation.
2. Systems Engineering programs are not increasing in number at the undergraduate level, but are expanding rapidly at the graduate level.
3. The influence of ABET is centered principally in the United States, whereas Systems Engineering is steadily expanding worldwide.
4. ABET is unlikely to embrace the full academic and professional potential of SE as promulgated by ASEE-SED, INCOSE, and others.

The vision for academic certification is predicated on the proposition that graduate study in Systems Engineering would produce more uniformly effective graduates if programs with certain desirable institutional and programmatic characteristics are recognized. Economically feasible web-based assessment to recognize quality outcomes could be initiated worldwide. Accordingly, certification of superb SE degree programs is being encouraged by some visionaries.

As a counterpart to professional certification of individuals, certification of Systems Engineering degree programs within academia may be timely for another important reason; What's in a Name? Academicians and practicing professionals alike are developing and applying powerful tools and methods for analysis, experimentation, modeling, simulation, etc. to the domain of operations. They permeate the fields of engineering management, industrial engineering, management science, operations research, systems analysis, and many others. The efforts and contributions of these individuals are often mistakenly considered to be Systems Engineering. These important techniques and methods are necessary, but not sufficient. SE is life-cycle process and synthesis centric and depends on all of the above for its effective execution.

Program certification is also suggested for engineering degrees with characteristics similar to those of Systems Engineering. These are increasing in number at the graduate level and have come into existence to satisfy voids created by the blurring of the domains in engineering education and practice. This prospectus is predicated on the proposition that selected programs similar to SE could be offered as a first professional degree. It supports and augments the recommendations found in the NAE publication, *Educating the Engineer of 2020*.[2]

The opportunity to provide an independent "outside-in" assessment of the scope and quality of academic programs worldwide is an idea whose time may be near. Consider, as an example, the following press release ***"****The University of Maryland's A. James Clark School of Engineering, one of the premier engineering schools in the U.S., has earned accreditation for three of its graduate degree programs from the Project Management Institute (PMI®) and the PMI Global Accreditation Center for Project Management (GAC). The first engineering school to be so accredited, the Clark School is also one of only three accredited schools in the U.S., and the sixth worldwide.* The press release continues *"Accreditation by PMI is achieved through a rigorous screening process that begins with a thorough self-study of an institution's project management program, followed by a report the school submits to the PMI GAC. If that report is approved, a team of professionals conducts a site visit, and in turn submits a final recommendation to the GAC."*[10]

Among other issues in the above example, is the opportunity to contemplate the use of the word *accreditation* by a professional society. In the context of this prospectus, the phrase *program certification* would have been used instead.

VII. GRCSE™ Provides a Unique Opportunity to Focus on Quality

Currently under collaborative development is an initiative entitled *Graduate Reference Curriculum for Systems Engineering* that provides a unique opportunity to focus on SE program quality. GRCSE is producing recommendations for Systems Centric master's degree programs in SE. Implementation guidance is included for institutions but, at this point, without reference to the availability of accreditation or the possibility of program certification.

GRCSE is one of two products of a larger project, the Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE™). The other product is the Guide to the Systems Engineering Body of Knowledge (SEBoK) for a professional master's degree focused on developing student ability to perform systems engineering tasks and roles.[11] Herein exists a unique opportunity to focus on either accreditation or certification as explicitly enabled by the objectives and outcomes based orientation of GRCSE. These include:

1. A set of objectives describing the near-term career goals of a graduate who successfully completes a graduate program based on the curriculum.
2. A set of outcomes to be met by a student to successfully complete a graduate program based on the curriculum.
3. A set of student skills, knowledge, and experience assumed by the curriculum for the entering student, not intended as entrance requirements for a specific program.
4. An architectural framework to communicate and support implementation of the curriculum with guidance on implementation and assessment.
5. A description of the Core Body of Knowledge (CorBoK) taught in the curriculum to achieve desired outcomes.

6. A set of use cases indicating how GRCSE will support the needs of various stakeholders using it for specific purposes.

GRCSE objectives have been determined. These are important statements about the future professional activities of program graduates. The objectives are intended to be used to set the program outcomes and to tailor the offerings of a program to support the career expectations of the student and employer communities.

There are key differentiators between programs, and these explain the diversity of program offerings. GRCSE recommends that all programs set formal objectives to help define the top-level requirements for their programs and offers the following sample objectives.

1. Effectively analyze, design, and implement feasible, suitable, effective, supportable, affordable, and integrated solutions throughout the life cycle of systems of systems, enterprises, services, and products. This could be tailored by explicitly stating the types of systems that graduates develop and a given domain (e.g., aerospace or telecommunications) or by specifying a portion of the system life cycle.
2. Successfully assume a variety of roles in multi-disciplinary teams of diverse membership, including technical expertise and leadership at various levels.
3. Demonstrate professionalism. Grow professionally through continued learning and involvement in professional activities. Contribute to the growth of the profession. Contribute to society through ethical and responsible behavior.
4. Communicate (read, write, speak, listen, and illustrate) effectively in oral, written, and newly developing modes and media, especially with stakeholders and colleagues.

Outcomes from GRCSE are statements about the competencies possessed by a graduate upon completion of the program. Ideally, outcomes are derived from objectives. Graduates of a master's program that aligns with the GRCSE recommendations will achieve a specified list of 13 outcomes. These are reminiscent of the outcomes character of accreditation under ABET.

Graduate systems engineering programs exist to provide a broad common framework for students coming from a wide variety of undergraduate backgrounds. To accommodate that breadth, GRCSE presumes that an entering student has:

1. The equivalent of an undergraduate degree in engineering, the natural sciences, mathematics, or computer science.
2. At least two years of practical experience in some aspect of systems engineering. This experience should include participation in teams and involvement in the life cycle of a system, subsystem, or system component.
3. Demonstrated ability to effectively communicate technical information, both orally and in writing, in a program's language of instruction.

VIII. Systems Engineering Status and Maturity

Engineering education has been subjected to in-depth study every decade or so, beginning with the Mann Report in 1918.[12] The most recent and authoritative study was conducted by the National Academy of Engineering (NAE) and published in 2005 under the title, *Educating the*

Engineer of 2020.[2] This section picks up on quality concerns for the 21st Century.

Engineering in the 21st Century. Although acknowledging that certain basics of engineering will not change, this NAE report concluded that the explosion of knowledge, the global economy, and the way engineers will work will reflect an ongoing evolution that gained momentum at the end of the twentieth century. The report gives three overarching trends to be reckoned with by engineering educators, interacting appropriately with engineering leaders in government and industry:

1. The economy in which we work will be strongly influenced by the global marketplace for engineering services, evidenced by the outsourcing of engineering jobs, a growing need for interdisciplinary and system-based approaches, demands for new paradigms of customization, and an increasingly international talent pool.
2. The steady integration of technology in our public infrastructures and lives will call for more involvement by engineers in the setting of public policy and for participation in the civic arena.
3. The external forces in society, the economy, and the professional environment will all challenge the stability of the engineering workforce and affect our ability to attract the most talented individuals to an engineering career.

SE Maturity for the 21st Century. Systems Engineering enters the 21st Century well positioned to contribute to the advancement of society. Continuing technological advances have created an increasing demand for engineers in most fields. But certain engineering and technical specialties will be merged or become obsolete with time. There will always be a demand for engineers who can synthesize and adapt to changes. The astute engineer should be able to detect trends and plan for satisfactory transitions by acquiring knowledge to broaden his or her capability.

It is encouraging to note that most schools and colleges of engineering are continually evolving their course offerings and degree requirements. Faculty members and administrators from these institutions meet periodically with corporate and governmental leaders to discover and consider changing needs. This same propensity compels most to seek formal peer approval in the form of programmatic accreditation through ABET, albeit limited to the undergraduate level.

Another sign of maturity is the ABET outcomes approach for the accreditation of academic programs. Instead of assessing the quantity and characteristics of input ingredients, ABET now relies on the academic institutions to set criteria for the output capability of graduates. This outcomes approach would also be appropriate for developing academic program certification.

Systems Engineering has experienced rapid growth in the commercial and governmental sectors. The need for Systems Engineering talent has increased beyond the available supply, and forward-looking enterprises and governmental agencies are increasingly helping to alleviate the problem through research, industry-academic collaboration, and advisory bodies.

The Systems Engineering process involves the use of appropriate technologies and management principles in a synergetic manner. Its application requires *synthesis* and a focus on process, along with a new *thought process* to meet 21st Century challenges.

IX. Summary and Recommendations

Systems Engineering entered this decade with considerable momentum. A maturing and focused professional society (INCOSE), along with explicit interest within the engineering domain societies as evidenced by the advent of ASEE-SED, and degree program evolution at all levels are probably the most tangible and visible connections between practicing professionals, academic institutions, and private and public enterprises. This paper proposes and describes initiatives that should be launched sequentially to establish SE as an international interdiscipline in service to humankind for this 21st century.

An increase occurred in the number of undergraduate DCSE programs and also in graduate programs within both the DCSE and SCSE categories. But, the number of undergraduate SCSE programs remained the same. Of concern is the fact that SE accreditation by ABET is *influencing just one-half* of all Systems Engineering degree programs in the United States. The equivalent situation beyond the US is largely unknown.

It is recommended that the idea of academic program certification for graduate programs be considered as a concurrent and companion step to altering the Multiple Lead Society approach adopted by ABET. Five steps are suggested, some sequential and others concurrent as follows:

1. Affirm the responsibility for the accreditation of Domain Centric SE programs; both basic and advanced, as being entirely on the cognizant domain societies within ABET along with the standing offer by INCOSE to support and collaborate when asked.
2. Place the entire responsibility for the accreditation of both basic and advanced Systems Centric SE programs on INCOSE, supported by those domain societies electing to assume a collaborative role, especially for programs at the basic level.
3. Launch an initiative to encourage universities to offer existing Systems Centric SE graduate programs for ABET accreditation. Only two do so at the present time.
4. Encourage institutions worldwide to apply for ABET accreditation for SE graduate programs in accordance with guidelines established by the existing and developing accords.
5. Failing recognizable progress with 3 and 4 above, launch an initiative to study, plan, and develop a global approach to academic program certification for Systems Centric SE along the lines suggested in this prospectus with an eye on GRCSE.

ASEE - SED has an opportunity and obligation to advance its interest in the quality of Systems Engineering education by diligently supporting the mission of ABET. Additionally, the opportunity to provide an independent "outside-in" assessment of the scope and quality of academic programs worldwide for certification is an idea whose time may be at hand as a fallback position.

References

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