Systems Engineering Degree Programs in the United States

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Abstract. The authors have observed a widespread need for general information regarding the availability and characteristics of Systems Engineering (SE) academic degree programs. This paper provides a compilation of SE degree programs in the United States, giving insight regarding academic content, administrative structure, accreditation status, and establishes a benchmark for the continued advancement of these degree programs. Description and analysis is offered by the authors to set a baseline that may be utilized to assess the future of existing and developing degree programs. The model for description and analysis utilized in this paper will be extended to the international domain in the near future.

Introduction

Systems Engineering degree programs are probably the most tangible and visible connection between academic institutions and the private and public domains comprising industry and government. Programs of study leading to basic and advanced degrees provide opportunities for individuals to prepare themselves for professional practice. Programs of advanced study within academia are promulgated concurrently with creative scholarship and research projects, with the benefits awaiting recognition within industry and government. Further, at the doctoral level, degree programs and research prepare individuals for the professorial ranks.

This paper will subject Systems Engineering degree programs as a whole to a number of classifications to facilitate discussion of their similarities, differences, and characteristics. 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 holds true for the meaning imparted to degree programs by academic administrators and faculty members. A degree program containing the SE designation at one institution may not be the same as a degree program with the same designation at another institution. Therefore, in considering the content of degree programs called Systems Engineering, one should go directly to the published curriculum and examine its course content.

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 the Accreditation Board for Engineering and Technology (ABET). The Systems Engineering "voice" of government, industry, and even academia will grow increasingly stronger as the International Council on Systems Engineering (INCOSE) continues to emerge as the lead society for the SE body of systematic knowledge.

Categories of Systems Engineering Degree Programs

Seventy five (75) institutions in the United States offer 130 undergraduate and graduate degree programs in Systems Engineering (SE). To facilitate analysis, we partition these programs into two broad categories: *Systems Engineering Centric Programs* (see Appendix A) and *Domain Centric Systems Engineering Programs* (see Appendix B).

Systems Engineering Centric (SEC) 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 as Systems Engineering; where SE is the intended major area of study.

There are currently 31 institutions offering 48 degree programs in the SE Centric category. The count by degree program level is given in Table 1:

Table 1. Systems Engineering Centric Programs (from Appendix A)

	BS		MS		PhD	
Program count	11	+	27	+	10	Total = 48

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. Included in this distinct category are those degree programs naming Systems Engineering along with a parent engineering domain.

There are currently 48 institutions (4 of these duplicate institutions on the Appendix A list) offering 82 Domain Centric Systems Engineering degree programs across the array of domains summarized in Table 2.

Table 2. Domain Centric Systems Engineering Programs (from Appendix B)

	BS	MS	PhD	
SE with Biological Engineering	16	5	3	24
SE with Computer Engineering	1	4	2	7
SE with Electrical Engineering		1		1
SE with Industrial Engineering	14	15	7	36
SE with Management Engineering		3	1	4
SE with Manufacturing Engineering	1	8	1	10
Totals	32	36	14	= 82

Organization and Administration of SE Degree Programs

Not all degree programs listed in this paper are administered through the classical departmental structure of the host institution. Although most undergraduate programs are classically organized, the following variants will be found:

1. There are instances where an academic administrative unit will be the home for more than one degree program or major; e.g., Systems Engineering and Industrial Engineering. The department name may or may not subsume the names of all degree programs.
2. There are instances where the institution will offer both a SE Centric (SEC) and a Domain Centric SE (DCSE) program; e.g., Systems Engineering and Manufacturing Systems Engineering. The DCSE program may be administered in an interdepartmental mode, whereas the SEC program will usually be administered within a department.
3. In those instances where an institution offers a SEC program at the basic and advanced levels, all are usually administered within a department. This is also true for DCSE programs, except that the SE component may not exist at all degree levels.

The above variants are mentioned to emphasize that one must be aware of the administrative and organizational home for a degree program of interest. The focus in this paper is always on the degree program itself. In discussing the basic and advanced level programs in the SEC and DCSE categories, this program focus will be strengthened by recognizing that Systems Engineering is broad in nature. It cannot be viewed in the same context as the traditional engineering disciplines. This notwithstanding, many domains of engineering are seeking a better technological balance by adopting systems thinking. This is the primary reason for the rapid growth in the number of engineering domains adding a systems component to their programs

Undergraduate Degree Programs in Systems Engineering

Forty three (43) of the 130 academic programs in Systems Engineering are at the undergraduate level (33% of the total). Eleven (11) out of the 48 (23% of the total) are SE Centric and 32 out of 82 (39% of the total) are Domain Centric SE. From this, one may infer that Systems Engineering is developing primarily at the graduate level, especially in the SE Centric category. Some cite this as evidence that SE study should requires a degree in an engineering domain as a prerequisite, with SE offered at the graduate level as a first professional degree.

With exceptions noted earlier, undergraduate degree programs in Systems Engineering are organized in departmental mode within a school or college of engineering, similar to any other academic program. The undergraduate approach to SE education is rarely interdepartmental in nature. Quite often these programs emphasize systems analysis in recognition of the demand on available time for other required courses. Synthesis and the systems engineering process is difficult to accommodate at the undergraduate level. They are normally reserved for an upper level capstone course, such as a senior design project, or for graduate study.

Programs of study at the undergraduate level are usually quite uniform for all registered engineering students. A standard curriculum is prescribed and published in the university catalog. Flexibility is usually limited by the number of electives allowed in the curriculum but, even then, the electives must be selected from approved lists. Development and modification of the curriculum is typically the responsibility of a departmental curriculum committee. University-wide curriculum review is normally used to review recommendations of the departmental committee against university curriculum policies. Outside review is popular at the undergraduate level, taking the form of oversight by the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET).

The departmental faculty is usually a closely-knit working group who teach the program to students in residence. There are few instances of undergraduate programs being offered off-campus, although some undergraduate courses are offered by distance learning methods.

An example of an undergraduate program in Systems Engineering from the Systems Engineering Centric (SEC) category is exhibited in Table 3. This degree program is not orientated toward any specific engineering domain. The characteristics of note are: 1) a strong foundation in mathematics, probability, and statistics as appropriate for systems modeling and analysis, 2) an almost complete absence of courses in the engineering sciences, 3) a broad list of systems analysis and computer science courses, and 4) some coursework in system design, including a capstone design project. More detail regarding this sample degree program and the courses it contains may be found at http://www.seas.virginia.edu/degree.php#undergraduate

Table 3. A Curriculum Leading to an Undergraduate Degree in Systems Engineering

First Semester			*Second Semester*		
APMA 111	Single Variable Calculus	4	APMA 212	Multivariate Calculus	4
CHEM 151	Intro. Chem. for Engr.	3	PHYS 142E	General Physics I	3
CHEM 151L	Intro. Chemistry Lab	1	PHYS 142W	Physics Workshop	1
ENGR 162	Intro. to Engineering	4	CS 101	Intro. to Computer Science	3
STS 101	Language Communication			Science Elective I	3
	in a Technological Society	3		HSS Elective	3
		15			17
Third Semester			*Fourth Semester*		
APMA 213	Ordinary Differential Eq.	4	APMA 310	Probability	3
PHYS 241E	General Physics II	3	APMA 308	Linear Algebra	3
PHYS 241W	Physics Workshop	1	SYS 202	Data and Information Engineering	3
CS 201	Software Devel. Methods	3	STS XXX	STS 2xx/3xx Elective	3
SYS 201	Systems Engr. Concepts	3		Science Elective II	3
	HSS Elective	3			15
		17			
Fifth Semester			*Sixth Semester*		
APMA 312	Statistics	3	SYS 334	System Evaluation	3
SYS 321	Deterministic Decision Models	3	SYS 360	Stochastic Decision Models	3
SYS 323	Human Machine Interface	3	SYS 362	Discrete Event Simulation	4
SYS 355	SE Design Colloquium I	1		Application Elective	3
	Technical Elective	3		Unrestricted Elective	3
	HSS Elective	3			16
		16			
Seventh Semester			*Eighth Semester*	The Engineer, Ethics, and Society	3
STS 401	Western Technology Culture	3		Systems Design II	3
SYS 421	Linear Statistical Models	4		Technical Elective	3
SYS 453	Systems Design I	3		Application Elective	3
SYS 455	SE Design Colloquium II	1		Unrestricted Elective	3
	Application Elective[(4)]	3			15
	Unrestricted Elective	3		Total Credits	128

In contrast to the SE Centric program above is an example of an undergraduate program from the Domain Centric SE (DCSE) category as exhibited in Table 4. This degree program is centric to the domain of Industrial Engineering with a systems orientation. The characteristics of note are: 1) a concentration on mathematics and statistics appropriate for systems analysis and modeling, 2) some recognition of the engineering sciences, 3) an extensive list of required Industrial Engineering courses, and 4) some coursework in system design, including a capstone senior design project. More detail regarding this sample degree program and the courses it contains may be found at http://www.usc.edu/dept/ise/academics/undergraddesc.html

Table 4. A Curriculum Leading to an Undergraduate Degree in Industrial and Systems Engineering

COMPOSITION/WRITING REQUIREMENT: 7 WRIT 140 Writing and Critical Reasoning (4) WRIT 340 Advanced Writing (3) **GENERAL EDUCATION: 20** Category III is fulfilled by PHYS/CHEM requirement **PRE-MAJOR REQUIREMENTS: 32** Mathematics Requirement MATH 125 Calculus I (4) MATH 126 Calculus II (4) MATH 226 Calculus III (4) MATH 225 Linear Algebra & Differential Equations (4) Physics Requirements PHYS 151 Fundamentals of Physics I (4) PHYS 152 Fundamentals of Physics II (4) Chemistry Elective MASC 110L Materials Science, or CHEM 105aL General Chemistry, or CHEM 115aL Advanced General Chemistry (4) Economics Requirement ECON 203 Principles of Microeconomics (4) **MAJOR REQUIREMENTS: 59** Business Course ACCT 410x Accounting for Non-Business Majors (4)	**MAJOR REQUIREMENTS (CONTINUED):** Electrical Engineering Course EE 326L Essentials of Electrical Engineering (4) Computer Science Courses CSCI 101 Fundamentals of Computer Programming (3) ISE 382 Introduction to Computer Systems, or CSCI 485 File and Database Management (3) Industrial and Systems Engineering Courses ISE 105a Introduction to Industrial & Systems Engineering (2) ISE 105b Introduction to Industrial & Systems Engineering (1) ISE 220 Probability Concepts in Engineering (3) ISE 225 Engineering Statistics I (3) ISE 232 Manufacturing Processes (3) ISE 310L Production I: Facilities and Logistics (4) ISE 330 Introduction to OR: Deterministic Models (3) ISE 331 Introduction to OR: Stochastic Models (3) ISE 370L Human Factors in Work Design (4) ISE 410 Production II: Production, Scheduling and Control (3) ISE 426 Statistical Quality Control (3) ISE 435 Discrete Systems Simulation (3) ISE 440 Work, Technology, and Organization (3) ISE 460 Engineering Economy (3) ISE 495 Senior Design Project (Fa: 1; Sp: 3) **MAJOR ELECTIVES: 10** Departmentally approved technical electives (4) Free Electives (6) **Total units required for the program: 128**

Graduate Degree Programs in Systems Engineering

Although conducted within a school or college of engineering, graduate programs normally come under the preview of the university acting through a Graduate School. The graduate school is an administrative unit under a Dean with operating policies for graduate study established by a Graduate Committee or Council. Students pursuing a graduate degree do not have a prescribed curriculum to follow as do undergraduates. They must develop a Plan of Study for approval by an advisory committee and the Graduate School.

The candidate's academic advisory committee for the Master's degree is normally composed of three individuals, with at least two being from the faculty (five individuals for the doctorate with at least three from the faculty). The non-faculty individuals may be selected from outside the University (industry, government agency, or equivalent). The Committee Chair must be a full-time member of the faculty, usually representing the engineering domain constituting the candidate's area of concentration.

The degree candidate is responsible for selecting his or her major professor (or Chairperson) and recommending the composition of an advisory committee to the Graduate School. Accordingly, he/she would approach a faculty member who conducts a class in the subject area and who expresses a willingness to serve as major professor. A subject concentration for course selection and the choice of the topic for research and thesis is then proposed for approval.

An example of a graduate program in Systems Engineering is exhibited in Table 5. This degree program is not orientated toward any specific engineering domain. It is an example from the Systems Engineering Centric (SEC) category. The characteristics of note are: 1) a strong orientation toward system architecture, system design, and evaluation, 2) concentration on engineering depth, 3) a strong list of systems analysis and computing courses, and 4) a group project or thesis requirement spanning one full year. More detail regarding this sample degree program may be found at http://www.cse.afit.edu/page.cfm?page=13&sub=54

Table 5. A Plan of Study leading to a Master of Science Degree in Systems Engineering

A sample education plan for an 18-month thesis student follows. The core courses and thesis credits are shown where they would typically appear in a plan of study. While only one engineering depth sequence is required for graduation, students normally take at least two engineering depth sequences (Tech Elective sequences A & B) as shown below. Total required quarter credits are 72.

Short Term Review
Calculus & Linear Algebra
Object Oriented Programming Design
Dynamics Review
Computers
Total - 4 Courses

1st Quarter–Fall
SENG 520 - Systems Engineering Design, 4
CSCE 593 - Introduction to SW Engineering, 4
XXXX xxx - Mathematics Course, 4
XXXX xxx - Tech Elective A I, 4 Eng. Depth
Total - 16

2nd Quarter–Winter
SENG 640 - Systems Architecture, 4
OPER 632 - Cost Analysis for System Design, 4
XXXX xxx - Tech Elective A II, 4 Eng. Depth
XXXX xxx - Elective, 4
Total - 16

3rd Quarter - Spring
SENG 610 - Systems Eng. Management, 4
XXX xxx - Tech Elective A III, 4 Eng. Depth
XXX xxx - Elective, 4
Total - 12

4th Quarter–Summer
SENG - 799 Thesis, 4
XXXX xxx - Tech Elective B I, 4 Eng. Depth
XXXX xxx - Elective, 4
Total - 12

5th Quarter–Fall
SENG - 799 Thesis, 4
XXXX - xxx Tech Elective B II, 4 Eng. Depth
Total - 8

6th Quarter–Winter
SENG - 799 Thesis, 4
XXXX - xxx Tech Elective B III, 4 Eng. Depth
Total - 8

The capstone of the SE program is the group design project. Typically, the students form a SE team and perform a group design study to be defended orally. However, in certain situations such as exists for part time students or single student classes, an individual thesis may be performed. The group project / thesis for the GSE program will be 12 credits of SENG 799, typically spread over three or more quarters. . In any case, the team or individual works on a major project of AF interest allowing the student to apply the systems approach to a real problem in a controlled environment.

In contrast to the SE Centric (SEC) graduate program above, is an example graduate program from the Domain Centric SE (DCSE) category, exhibited in Table 6. This degree program is directed toward the domain of Manufacturing Systems Engineering. The characteristics of note are: 1) an orientation toward competitive manufacturing to be developed through four core courses, 2) some orientation toward corporate strategy for manufacturing, including agile manufacturing systems, 3) little coursework in traditional manufacturing engineering science, 4) a strong list of required manufacturing systems engineering courses, and 5) a project or research thesis, with the project having an industrial problem focus. More detail regarding this sample degree program may be found at http://www.lehigh.edu/~inmse/gradprogram/curriculum.html

Table 6. A Plan of Study Leading to a Masters of Science Degree in Manufacturing Systems Engineering.

Four Core Courses are required of all candidates for the Master of Science in Manufacturing Systems Engineering degree. These are:

MSE 421 - Technology, Operations, and Competitive Strategy
MSE 362 - Logistics and Supply Chain Management
MSE 427 - Automation and Production Systems
MSE 438 - Agile Organizations and Manufacturing Systems

Elective Courses - In addition to the core courses, students must complete at least 4 - 5 graduate level elective courses to complete the minimum 30 credit hours towards their degree. For students pursuing the thesis option the minimum number of electives is four; for students undertaking a project, the minimum number of elective courses is five. It is a requirement that at least one elective is an MSE-numbered course.

Electives are chosen by each student, in consultation with an academic adviser. Electives should be chosen which meet an individual's technical and professional development needs. Electives may be selected from graduate course offerings in the Colleges of Engineering and Applied Science and Business and Economics to provide a balance of technical and business courses in each student's program.

MSE 423 - Product Design / Analysis
MSE 431 - Marketing and the Invention to Innovative Processes
MSE 433 - Technology and the Factory of the Future
MSE 446 - International Supply Chain Management
MSE 496 - Microelectronics Manufacturing Systems and Technologies
MSE 498 - Special Topics

Project / Thesis Option - MSE degree candidates must complete either an engineering project or a research thesis. Project SE - 451) - The three credit hour project focuses on the analysis and solution to an engineering problem. It can take the form of a simulation study, development of a software package, implementing a hardware system, analyzing and/or designing a manufacturing system or modification thereof. The results of project activity should afford benefit to a company.

Interdisciplinary Graduate Programs in Systems Engineering

When an academic institution augments its traditional discipline structure with interdisciplinary centers, clusters, institutes, and programs, Systems Engineering is often included in the planning. The body of knowledge in Systems Engineering principles is gaining recognition, causing a strong demand for the SE Centric approach to augment engineering domain manifestations of SE. Under these conditions, it is essential that a SE Program Advisory Committee (SEPAC) be organized at the school or college level to represent the participating departments.

It is evident that the normal or typical graduate school administrative structure described in the prior section can accommodate degree candidates who choose to stretch their experience in Systems Engineering by incorporating interdisciplinary elements. However, faculty members from the participating departments must assume the responsibility and authority to define, develop, implement, and achieve program objectives based on stakeholder needs and inputs. This includes the establishment of program requirements pertaining to academic content (i.e., admissions criteria, course selection, student plans of study, project/thesis guidelines, final examinations/defenses, and exit criteria). This SEPAC should meet at least once each semester and be responsible not only to ensure that all academic requirements are met, but to provide ongoing review and evaluation of program output and effectiveness relative to resources allocated to the interdepartmental effort.

The SE Program Advisory Committee should consist of three to five members of the engineering faculty, one from each of the participating engineering disciplines. The faculty selected for these positions should be appointed and supported by the appropriate academic Department Head. The responsible Chairperson should be a SEPAC member with the academic rank of Associate Professor (or higher) with tenure. The Program Chairperson will work closely with the SE PAC relative to matters of an academic and programmatic nature, and with the Dean or Associate Dean of Engineering on matters of an administrative and fiscal nature.

Degree candidates enrolled in an interdisciplinary graduate program will be registered in one of the participating departments. His/her personal advisory committee should be formed under a major professor in one department. The candidate will also identify and request two other qualified individuals to serve on the advisory committee. At least one of these individuals must be a full-time member of the faculty. One other can be a professional from industry, a government agency, or equivalent, as long as there is no conflict of interest relative to inhibiting the candidate from pursuing the desired project or area of research. The committee composition should be interdisciplinary, to align with the plan of study and project topic.

There have been a number of interdisciplinary or interdepartmental degree programs established in schools and colleges of engineering as early as the 1960's. Even smaller colleges will likely find members of its faculty with the maturity and interest to collaborate in the offering of graduate study in Systems Engineering. The motivation for doing so, particularly at the Masters level, often comes from practicing engineers in the area, with encouragement from their companies and governmental agencies. With the advent of INCOSE in the 1990's, a number of academically inclined members have worked diligently to establish SE degree programs within their local institutions worldwide.

An example set of guidelines for an interdisciplinary graduate program in Systems Engineering is exhibited in Table 7. This interdepartmental initiative was established in 1968 and the first M.S. degree was awarded in 1972. Through 1995-96, more than 350 practicing engineers received their Masters degree under this interdisciplinary mode. The total to date exceeds 500. More information regarding this program is available at http://www.ise.vt.edu

Table 7. Example Interdepartmental (Interdisciplinary) Guidelines for the Masters Degree in SE

Three required courses: ENGR 5004 - The SE Process, ENGR 5105 – Applied SE, and ENGR 5904 – Project and Report or ENGR 5994 – Research and Thesis.
Four engineering domain courses: At least 12 credits from the SE oriented courses in an engineering department (i.e., AOE, CE, IE, etc.).
Other engineering domain courses: At least 6 credits from the SE oriented courses in another engineering departments.
Non-engineering courses: At least 3 credits outside of engineering.
Final oral examination: A defense of the report or thesis before an interdisciplinary committee of three with general questioning.

During 1995-96, the decision was made to shift the Systems Engineering graduate program administratively and fiscally from the Office of the Dean of Engineering to the Department of Industrial and Systems Engineering (ISE). The intent was for Systems Engineering to continue as an interdisciplinary program within the College of Engineering, with each participating department playing its former role. But, the natural dominance of the disciplines over the interdisciplinary can be problematic. Vigilance is required to maintain interdepartmental cooperation when the program focus ceases to be at the college level.

Details regarding the sample program in Table 7 (program organization, administration, academic structure and related matters) are available in the *Program Description and Charter for the Interdisciplinary Graduate Program in Systems Engineering*, July1996. It may be obtained from www.a2i2.com

Accreditation of Systems Engineering Degree Programs

Currently there is no professional society (and no specific criteria) for accrediting academic degree programs in Systems Engineering. At present, Systems engineering programs are accredited by ABET upon request under a special or "Other" category. The SE programs now accredited in this manner are found at www.abet.org and exhibited in Table 8.

Table 8. Systems Engineering Programs Accredited Under the ABET 'Other' Category

Institution	Degree Program	Classification
Air Force Institute of Technology	M.S. in Systems Engineering	SEC
Case Western Reserve University	B.S. in Systems and Control Engineering	SEC
George Mason University	B.S. in Systems Engineering	SEC
Oakland University	B.S. in Systems Engineering	SEC
Ohio State University	B.S. in Industrial and Systems Engineering	DCSE
Rensselaer Polytechnic Institute	B.S. in Computer and Systems Engineering	DCSE
San Jose State University	B.S. in Industrial and Systems Engineering	DCSE
State University of NY at Binghamton	B.S. in Systems and Industrial Engineering	DCSE
United States Military Academy	B.S. in Systems Engineering	SEC
United States Naval Academy	B.S. in Systems Engineering	SEC
University of Arizona	B.S. in Systems Engineering	SEC
University of Arkansas at Little Rock	B.S. in Systems Engineering	SEC
University of Florida	B.S. in Industrial and Systems Engineering	SEC
University of Pennsylvania	B.S. in Systems Science and Engineering	SEC
University of Virginia	B.S. in Systems Engineering	SEC
Virginia Tech	B.S, in Industrial and Systems Engineering	DCSE
Washington University	B.S. in Systems Science and Engineering	SEC
Wright State University	B.S. in Industrial and Systems Engineering	DCSE
Youngstown State University	B.S. in Industrial and Systems Engineering	DCSE

The Accreditation Board for Engineering and Technology. The Accreditation Board for Engineering and Technology (ABET) is the professional body that accredits academic programs in engineering and engineering technology. This is accomplished through the Engineering Accreditation Commission (EAC) of ABET. 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. The mission of ABET is accomplished through the professional engineering societies serving as participating bodies. The International Council on Systems Engineering hopes to become a participating body very soon.

Anticipated INCOSE Role Within ABET. INCOSE aspires to become the lead professional society for accrediting Systems Engineering programs through ABET. Program criteria, now being established at the basic and advanced levels for these programs, will emphasize the process and means embraced by the INCOSE definition of Systems Engineering, as well as the need for systems thinking within the profession of engineering. INCOSE has a unique dual role to fulfill within ABET. Systems Engineering Centric (SEC) programs provide one academic population and Domain Centric SE Programs (DCSE) provide another. The latter must be pursued in cooperation with the participating bodies representing the domains of engineering.

The International Council on Systems Engineering (INCOSE) is the leading professional society with an inherent capability and keen desire to determine and implement appropriate criteria for Systems Engineering accreditation. INCOSE was founded in 1990 and is now solidly established and rapidly expanding domestically and internationally. Its activities are focused to develop, nurture, and enhance the interdisciplinary approach in the realization of successful systems via its strong and enduring ties with industry, academia, and government. In this symbiotic relationship, INCOSE will continue to:

1. Provide a focal point for dissemination of Systems Engineering knowledge.
2. Promote collaboration in Systems Engineering education and research.
3. Assure the establishment of professional standards for integrity in the practice of Systems Engineering.
4. Improve the professional status of persons engaged in the practice of Systems Engineering.
5. Encourage governmental and industrial support for research and educational programs that will improve the Systems Engineering process and its practice.

INCOSE has an opportunity and obligation to advance its interest in the quality of Systems Engineering education by offering to support the mission of ABET. The ABET opportunity is viewed by INCOSE to be critical to the advancement of SE in its own right as well as essential to the infusion of SE thinking within the domain manifestations of engineering. INCOSE desires to lead in the category of SE Centric programs and collaborate with the professional bodies now participating in ABET for Domain Centric SE programs.

Tentative Program Criteria. Criteria for the accreditation of Systems Engineering programs at the basic level are based upon the published General ABET Criteria for those institutions offering the program at the basic 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. This is in addition to the basic level criteria. INCOSE fully supports 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. Perticipating bodies provide the criteria and institutions choose the accreditation level to be sought.

Program criteria unique to Systems Engineering emphasizes certain characteristics that must be present in the curriculum. Additionally, the program faculty must be able to impart an understanding of systems thinking by virtue of their academic preparation and professional experience. Specific criteria applicable to curriculum and to faculty currently under discussion and development and are:

1. Curriculum **-** The program must demonstrate that graduates have the ability to participate in the design and integration of effective, life-cycle balanced systems by addressing the form, fit, and function of both the product and the development process. An emphasis on system design for successful life-cycle outcomes must be present, with evidence that the curriculum provides preparation for engineering practice as part of a development team.

2. Faculty **-** Evidence must be provided to show that most of the program faculty have a personal knowledge of professional practice in Systems Engineering and analysis, including an understanding of at least one version of the systems engineering process. Faculty must have the responsibility and authority to define, develop, implement, and achieve program objectives based on stakeholder needs.

Application of Program Criteria. ABET leaves it to the institution to choose the 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 undergraduate (basic) or the advanced level. Of course, opportunity for choice exists only in those program areas for which criteria have been established at both levels. The current mandate is for INCOSE to develop and implement criteria for both basic and advanced level accreditation.

INCOSE is well prepared to support ABET in the accreditation process with the appropriate resources and dedicated individuals. Many INCOSE members hold advanced degrees and all are practicing engineering professionals. All are vitally interested and committed to the quality and vision of Systems Engineering education and research.

Summary and Conclusions

Several classifications of Systems Engineering degree programs were adopted in this paper; SE Centric, Domain Centric SE, Undergraduate SEC and DCSE, Graduate SEC and DCSE at both the Masters and Doctoral levels, and finally, Interdisciplinary Graduate SE. Although elaborate, complete insight into the complexity of Systems Engineering academic degree programs would not be possible without this taxonomy. The taxonomy was then populated by a compilation of 130 degree programs offered by 75 independent institutions in the United States. The results were presented in two Appendix Tables (A and B).

It is evident that Systems Engineering education in the United States is itself a system and can be argued to bear out two qualities inherent in the systems concept; the first, a locus for innovation, malleability, and variety; the second, contemporaneous usefulness and a semblance of permanence when any particular point of perfection has been achieved. Accordingly, the authors invite consideration of other models of description and analysis that could provide classification insight beyond that offered herein.

Since cross-currents of study and professional advancement run life-long and cross all geographic and national boundaries, and the workplace is anywhere on the globe, engineers need more and more to speak each others' language. Schools and colleges of engineering in the United States are the loci for the study reported in this paper. But the effort applied must not stop there. Accordingly, the authors affirm that the rationale of this paper is solely theirs and invite educators, professional engineering societies, and individuals in industry and government to invest their best thought into the unfolding issues worldwide.

Systems Engineering has experienced rapid growth in the commercial and governmental sectors. The need for talent in SE has increased beyond the available supply, and forward-looking corporations and governmental agencies are increasingly interested in helping to alleviate the problem. We hope that the findings in this paper will contribute appropriate insight.

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APPENDICES

APPENDIX A - Systems Engineering Centric (SEC) Programs

Institution	Degree Programs
Air Force Institute of Technology	M.S. in Systems Engineering
Arlington State University	M.S. in Systems Engineering
Boston University	Ph.D. in Systems Engineering
Case Western Reserve University	B.S., M.S., Ph.D. in Systems and Control Engineering
Colorado School of Mines	M.E., M.S., Ph.D. in Engineering Systems
Cornell University	M.S. in Engineering / Systems Engineering Option
George Mason University	B.S., M.S. in Systems Engineering
George Washington University	B.S., M.S., Ph.D. in Systems Analysis and Engineering
Iowa State University	M.S. in Systems Engineering
Johns Hopkins University	M.S. in Systems Engineering
Naval Postgraduate School	M.S. in Systems Engineering
Oakland University	B.S., M.S., Ph.D. in Systems Engineering
Polytechnic University at Farmingdale	M.S. in Systems Engineering
Portland State University	M.E. in Engineering / Systems Engineering Option
Rochester Institute of Technology	M.E. in Systems Engineering
Southern Methodist University	M.S. in Systems Engineering
Southern Polytechnic State University	M.S. in Systems Engineering
Stevens Institute of Technology	M.E. in Systems Engineering
United States Military Academy	B.S. in Systems Engineering
United States Naval Academy	B.S. in Systems Engineering
University of Alabama at Huntsville	M.S.E., Ph.D. in Systems Engineering
University of Arizona	B.S., M.S., Ph.D. in Systems Engineering
University of Arkansas at Little Rock	B.S. in Systems Engineering
University of Idaho	M.E. in Systems Engineering
University of Maryland	M.S. in Systems Engineering
University of Missouri at Rolla	M.S. in Systems Engineering
University of Pennsylvania	B.S., M.S.E., Ph.D. in Systems Science and Engineering
University of Southern California	M.S. in Systems Architecture and Engineering
University of Virginia	B.S., M.S., Ph.D. in Systems Engineering
Virginia Tech	M.S., M.E. in Systems Engineering
Washington University	B.S., M.S., Ph.D. in Systems Science and Engineering

Data in these tables was obtained from *Peterson's Guide to Graduate Programs in Engineering and Applied Sciences*, Thompson Learning, 2004 and other sources. More detail is available from the authors or from http://www.a2.2.com

APPENDIX B - Domain Centric Systems Engineering (DCSE) Programs

Institution	Degree Programs
Auburn University	B.S. in Biosystems Engineering B.S., M.S. in Manufacturing Systems Engineering M.E.,M.S., Ph.D. in Industrial and Systems Engineering
Boston University	M.S. in Computer Systems Engineering
California State University at Fullerton	M.S. in Electrical Engineering / Systems Engineering Option
Clemson University	B.S. in Systems Bioengineering
Florida A and M University	B.S. in Biological and Agricultural Systems Engineering
Lehigh University	M.S. in Manufacturing Systems Engineering
Massachusetts Institute of Technology	Ph.D. in Engineering Systems
Michigan State University	B.S. in Biosystems Engineering
New Jersey Institute of Technology	M.S. in Manufacturing Systems Engineering
North Carolina A and T University	B.S. in Agricultural and Biosystems Engineering
North Dakota State University	B.S. in Agricultural and Biosystems Engineering
Northeastern University	M.S., Ph.D. in Computer Systems Engineering
Ohio State University	B.S., M.S., Ph.D. in Industrial and Systems Engineering
Oklahoma State University	B.S., M.S. in Industrial and Manufacturing Systems Engineering
	B.S., M.S., Ph.D. in Biosystems Engineering
Polytechnic University	M.S. in Information Systems Engineering and Systems Integration
Purdue University	Ph.D. in Manufacturing and Production Systems Engineering
Rensselear Polytechnic Institute	M.S. in Manufacturing Systems Engineering B.S., M.S., Ph.D. in Computer and Systems Engineering
Rutgers, The State University	B.S., M.S., Ph.D. in Industrial and Systems Engineering
San Jose State University	B.S., M.S. in Industrial and Systems Engineering
South Dakota State University	B.S. in Agricultural and Biosystems Engineering
Stanford University	M.S. in Manufacturing Systems Engineering
State University of NY at Binghamton	B.S., M.S., Ph.D. in Systems and Industrial Engineering
Tennessee Tech University	B.S. in Industrial and Systems Engineering
Texas Tech University	M.S. in Manufacturing Systems and Engineering
University of Arizona	B.S. in Agricultural and Biosystems Engineering
University of California, Davis	B.S. in Biological Systems Engineering
University of Central Florida	M.S. in Systems Engineering and Management
University of Florida	B.S., M.S., Ph.D. in Industrial and Systems Engineering
University of Hawaii at Manoa	B.S. in Biosystems Engineering
University of Houston	M.S. in Computer and Systems Engineering
University of Idaho	M.S. in Biological Systems Engineering
University of Memphis	B.S., M.S. in Industrial and Systems Engineering
University of Michigan	M.S. in Industrial Engineering with concentration in Systems
University of Michigan at Dearborn	M.S. in Industrial and Systems Engineering M.S.E. in Industrial and Manufacturing Systems Engineering
University of Minnesota	B.S. in Biosystems and Agricultural Engineering M.S. in Infrastructure Systems Engineering

University of Nebraska at Lincoln	M.S. in Biological Systems Engineering
University of Pittsburgh	M.S. in Manufacturing Systems Engineering
University of South Florida	B.S., M.S.E. in Industrial and Management Systems Engineering
University of Southern California	B.S., M.S., Ph.D. in Industrial and Systems Engineering
University of Southern Colorado	B.S., M.E. in Industrial and Systems Engineering
University of St. Thomas	M.S. in Manufacturing Systems Engineering
University of Tennessee	B.S. in Biosystems Engineering
University of Wisconsin	B.S. in Biological Systems Engineering
Virginia Tech	B.S., M.S., Ph.D. in Biological Systems Engineering B.S., M.S., Ph.D. in Industrial and Systems Engineering
Washington State University	B.S., M.S., Ph.D. in Biological Systems Engineering
Wright State University	B.S., M.S. in Industrial and Systems Engineering
Youngstown State University	B.E., M.S. in Industrial and Systems Engineering

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Biographical Sketches

Wolter J. Fabrycky is chairman of Academic Applications International, Inc. He is also the Lawrence Professor Emeritus of Industrial and Systems Engineering at Virginia Tech and a Registered Professional Engineer in both Arkansas and Virginia. Dr. Fabrycky joined Virginia Tech in 1965 where he served as Founding Chairman of Systems Engineering, Associate Dean of Engineering, and then as Dean of Research for the University. He was named an INCOSE Fellow in 1998 and received INCOSE's Pioneer Award in 2000. Fabrycky is co-author of six Prentice Hall engineering textbooks and co-edits the Prentice-Hall International series in Industrial and Systems Engineering.

Elizabeth A. McCrae directs the Corporate Administrative Operations for Academic Applications International, Inc. She received her doctorate from Boston University in 1974, and subsequently served on the administrative staff of the Boston University School for the Arts from 1978 through 1983. In the arts arena, Dr. McCrae has been the executive administrator for Alea III, the Founding Director for Summerstrings, and served as President of the Chromatic Club of Boston. Dr. McCrae has recently taken on the challenge of collecting, organizing, updating, and communicating the national and international information database pertaining to Systems Engineering and its engineering domain manifestations.