Indiana University Purdue University Indianapolis
Request for a New Graduate Certificate Program

Campus: U Indianapolis (IUPUI)

Proposed Title of Graduate Certificate Program: SYSTEMS ENGINEERING

Department/Program and School Proposing Certificate: Department of Mechanical Engineering (ME), Purdue School of Engineering & Technology (ENGT)

Projected Date of Implementation: Fall 2006

I. GRADUATE SCHOOL AFFILIATION OF CERTIFICATE: (check one)

- ✓ PURDUE UNIVERSITY – These certificates meet the general requirements of Purdue and are approved by the Purdue Graduate School, after approval at IUPUI
- ❑ INDIANA UNIVERSITY – These certificates are proposed by units that are subject to the authority of the IU Graduate School, meet the general requirements of IU, and are approved by the IU Graduate School, after approval at IUPUI
- ❑ INDIANA UNIVERSITY -- These certificates are proposed by units that are not subject to the authority of the IU Graduate School and are referred directly to the Academic Leadership Council after approval at IUPUI

II. TYPE OF CERTIFICATE: (check one)

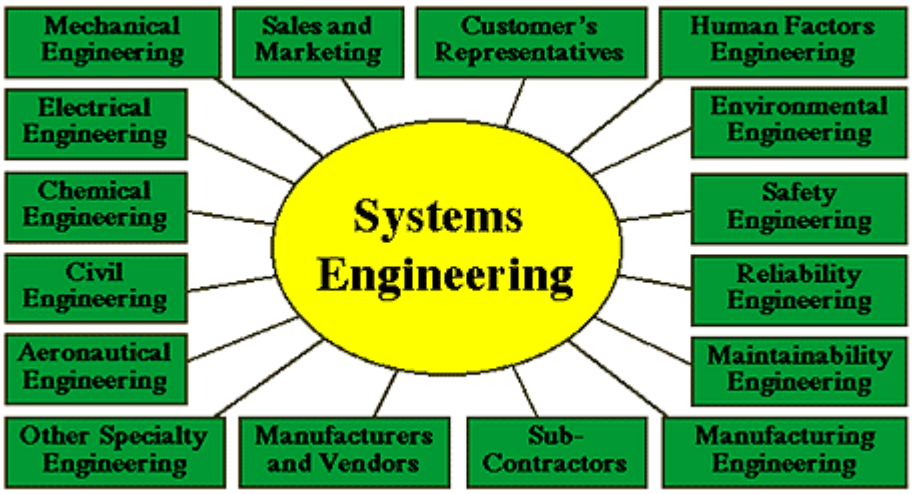
- ❑ AREA CERTIFICATES – These are specialty certificates, often interdisciplinary, which are awarded concurrently with or subsequent to a baccalaureate, masters, or doctoral degree. In one sense, they are like an additional major or minor, and their content may or may not be related to the degree.
- ✓ REGULAR CERTIFICATES – These programs generally require one semester to one year of academic work. They are structured programs which utilize regular academic credit courses. This type of certificate program corresponds with the ICHE definition of certificate programs.
- ❑ UNIT AWARDED CERTIFICATE – These are granted by sub-units of the university for certain kinds of specialized training or education. They are not recognized as being university awarded but rather unit awarded, and may not only utilize credit bearing courses.

III. Why is this certificate needed? (State the purpose and rationale of the program)

Background

Systems Engineering is a multi-disciplinary field that aims at integrating the engineering and management functions in the development and creation of a product, process, or service. The definition given by International Council on Systems Engineering (INCOSE) is a good description of what SE encompasses: "Systems Engineering is concerned with the overall process of defining, developing, operating, maintaining, and ultimately replacing quality systems. While other engineering disciplines concentrate on the details of individual aspects of a system (electronics, mechanics, ergonometrics, aerodynamics, software, etc.), Systems Engineering is concerned with the integration of all of these aspects into a coherent and effective system. Systems engineers concentrate their efforts on the aspects of the engineering process (requirements definition, top-level functional designs, project management, life cycle cost analysis,...) that serve to organize and coordinate other engineering activities. The systems engineer is the primary interface between management, customers, suppliers, and specialty engineers in the systems development process." Based on this description, all engineering and manufacturing firms, and many other complex institutions, need Systems Engineering to improve productivity and quality.

The following schematic shows how Systems Engineering typically forms a link for all the other disciplines and functions in a broad engineering organization. Similar schematics may be developed for institutions in specialized fields.



Need in Central Indiana

The Purdue School of Engineering and Technology (ENGT) was advised by its Dean's Industrial Advisory Committee (DIAC) that there is an unfulfilled need among companies in central Indiana for training and supply of qualified systems engineers.

An ad hoc DIAC Committee on Systems Engineering was appointed by the Dean of ENGT, and after a careful study, the committee members agreed that there is a need from local companies for employee education in the discipline of Systems Engineering. Industry members on the

committee pointed out that it is difficult for local industry to find candidates with the specific training in SE. Companies typically have to rely on on-the-job training to give engineers the necessary knowledge to work in the Systems Engineering area. ENGT also receives inquiries about course and degree offerings in Systems Engineering.

A recent seminar offered by the Central Indiana Section of INCOSE was filled to capacity by employees from local companies. About 45 people attended the INCOSE seminar, representing all the major companies in Central Indiana, including Rolls Royce, Raytheon, Delphi, Cummins, and Lilly. According to a seminar organizer, many others who wanted to attend were left out because of the overwhelming response. During a discussion at the ICOSE seminar, representatives from industry made it clear that there is a need for a graduate level program in Systems Engineering in Central Indiana.

In February 2006, an INCOSE education fair was held at IUPUI, with presentations by several Indiana schools about programs in Systems Engineering. This was also well attended, and it was clear that other schools are forging ahead with similar programs in the Fort Wayne and Terre Haute areas, but there is no Systems Engineering program in the Indianapolis area yet. From a survey conducted during this meeting, it appears that there is significant interest in either a certificate or a masters' level program in Systems Engineering.

The above cited studies are the basis for the proposed Systems Engineering Certificate Program to be offered by ENGT at IUPUI.

IV. List the major topics and curriculum of the certificate. A course list including course descriptions is required. If new courses are proposed for the program, include copies of the paperwork for course submission.

There will be two required courses, and two elective courses.

The following are required courses for the Systems Engineering Certificate program:

a. SE 5xx Introduction to Systems Engineering Principles
b. SE 5xx System Modeling and Analysis

Elective courses will be selected from the following list of courses that may be offered. The SE5xx courses will be developed when justified by student interest and resources. At least one of the elective courses must be from the Systems Engineering program, i.e. SE courses. The other elective may be selected from among the listed ME, ECE, or STAT courses.

c. SE 5xx Systems Architecting
d. SE 5xx Project Management & Risk Analysis
e. SE 5xx Requirements Elicitation and Requirements Management
f. SE 5xx Human Factors in System Performance
g. SE 5xx Systems Financial and Contract Management
h. SE 5xx Health Care Management using Systems Engineering

i. SE 5xx Supply Chain, Logistics and Transportation Systems
j. SE 5xx Concurrent Engineering and Integrated Product Development Systems
k. SE 5xx Product Lifecycle Management
l. ME 575 Theory and Design of Control Systems
m. ME 581 Numerical Methods in Mechanical Engineering
n. ME 597 Advanced Mechanical Engineering Projects I (3cr)
o. ECE 536 Introduction to Computational Intelligence
p. ECE 565 Computer Architecture
q. ECE 515 Software Engineering Methodology
r. ECE 580 Optimization Methods for Systems and Control
s. ECE 602 Lumped System Theory
t. ECE 680 Modern Automatic Control
u. STAT 511 Statistical Methods I
v. STAT 512 Applied Regression Analysis
w. STAT 514 Designs of Experiments

Course descriptions are given in the Appendix. Elective SE courses will be described as resources become available to develop these courses.

V. What are the admission requirements and admission procedures?

To be admitted to the proposed Certificate Program a candidate should meet the following requirements:

1. A bachelors degree in an engineering field from an ABET accredited or equivalent recognized institution, or in a field of science or technology with strong mathematical background, from an accredited or recognized institution.
2. An undergraduate GPA above 3.0 on a 4.0 scale.
3. For international students, a minimum TOEFL score of 550.

Students admitted into any of the engineering graduate degree programs are also eligible for the SE Certificate Program.

VI. List the major student outcomes (or set of performance based standards) for the proposed certificate. Completion requirements should be clearly stated, along with procedures for audit and certification.

The major outcome of this program is that the students will gain a good understanding of Systems Engineering principles, practices, and methods. This will enable them to apply the systems approach in advanced manufacturing, life sciences, and other fields where complex systems and high-tech products are developed, and diverse performance and regulatory requirements apply.

The graduate level Systems Engineering Certificate will be awarded when the student has fulfilled the following requirements:

1. Completed 12 credit hours of graduate course work, taken for letter grades, chosen from the list of courses listed in Section IV above, with a C or better grade.
2. Received an overall GPA of 3.0 or higher.

The following restrictions apply:

1. A maximum of 3 credit hours of equivalent coursework may be transferred from another institution.
2. A maximum of 6 credit hours earned prior to enrollment in the program, including work at other institutions, may be applied towards the certificate program.
3. No undergraduate courses may be used for the graduate certificate program.
4. A maximum of 4 years is allowed for the completion of the certificate program. Exceptions may be approved by the ENGT Graduate Education Committee.
5. The courses earned for the SE Certificate Program cannot be used for another certificate program within ENGT, but may be used towards a graduate degree program.

VII. Explain how student outcomes will be assessed (course-embedded assessments, graduate follow-up, employer survey, standardized tests, etc.).

The program outcomes will be assessed by surveys of employers of SE graduates, self-assessment of graduating students, and a follow-up survey of alumni after graduating significant number of students.

Course outcomes will be written for each course. The outcomes will be measured using multiple methods, including student performance on assigned tasks, examinations, and projects, self-assessment surveys, and juries of faculty and industry representatives.

VIII. Describe procedures for program evaluation including the criteria for success

The program will be evaluated based on the level of enrollment, satisfaction of employers, and the success of graduates from the program.

IX. Describe student population to be served, including evidence of need and what proportion of students are expected to be concurrently working toward a graduate degree at IUPUI.

The SE Certificate Program aims at helping local industry to train qualified engineers to work in the area of Systems Engineering. The primary targets are practitioners in the industry who are either working in the area but have not had any formal training in the area, or are interested in moving into the SE area.

As has been mentioned in Section I, local industry currently has not been able to hire directly candidates with a formal education in SE and often have to rely on on-the-job training to move engineers from other disciplines into the positions of systems engineers. There is a clear need in industry, especially in central Indiana, for an educational program to help train employees in this area.

Some SE students may also be working towards graduate degrees in Engineering, Technology, Science, Medicine, Health Sciences, Management, Public Policy, Informatics, or other fields of study at IUPUI, and may also use SE credits towards such degrees, as allowed by those programs.

X. How does this certificate complement the campus or departmental mission?

This certificate program is consistent with the missions of IUPUI, the School and Department. The Department mission includes service to local engineering needs, and the School mission emphasizes the provision of high-quality, well-rounded educational experiences in an urban environment. It is expected that the degree will fulfill the IUPUI mission to provide its constituents with excellence in learning in an urban university, characterized by collaboration across and within disciplines and within the community.

The SE program is inherently multi-disciplinary and requires strong collaboration among engineering departments. In addition, it will complement existing dual degree programs that ME has with the Department of Physics and the School of Business.

XI. Clarify the relation of the proposed certificate to relevant existing or proposed undergraduate, graduate, or certificate programs, if any, at IUPUI or elsewhere at Indiana University.

The program is being developed collaboratively by faculty in the engineering departments of the Purdue School of Engineering and Technology, IUPUI. There is no known similar program at IUPUI or IU. When the Systems Engineering certificate program is mature and stable, it may grow into a graduate degree program, or lead students to graduate degrees in other engineering disciplines: industrial, mechanical, electrical, computer, biomedical.

It is intended that the program eventually form the case of a masters' program in Engineering Management, which will be developed as the SE certificate program becomes established with sufficient new resources as described below.

Some SE students may also be working towards graduate degrees in Engineering, Technology, Science, Medicine, Health Sciences, Management, Public Policy, Informatics, or other fields of study at IUPUI, and may also use SE credits towards such degrees, as allowed by those programs.

XII. List and indicate the resources required to implement the proposed program. Indicate sources (e.g., reallocations or any new resources such as funding, space, personnel, library holdings, equipment, etc.).

The most important resources needed are personnel: faculty members qualified to conduct the program and teach courses. At present, there are no faculty members at IUPUI with qualifications specifically in Systems Engineering. Competing schools have hired such faculty, and IPFW has hired a senior professor into an endowed Systems Engineering chair position created for their new program.

The Department of ME needs to hire two tenure-track faculty members with research expertise in Systems Engineering and Engineering Management to become the champions and experts of this program. The base funding for these positions will be an essential requirement for creating this program. These faculty will also develop the MS program in Engineering Management, with input from the other engineering departments and local industry.

It will also be necessary to provide release time for current engineering faulty to develop related courses. Industry practitioners in Systems Engineering will be invited to teach some of the courses listed above.

XIII. Describe any innovative features of the program (e.g., involvement with local or regional agencies, or offices, cooperative efforts with other institutions, etc.).

The program will involve local industry very closely in setting guidelines for the curriculum, participation of adjunct faculty from industry, and student recruitment. The program is multi-disciplinary, involving courses and faculty from multiple engineering departments, as well as Mathematical Sciences.

XIV. What is the plan for attaining steady-state enrollment. Include the number of students expected to participate in the program in the first year and an enrollment projection for the year in which steady-state enrollment is expected.

The industry members predicted that there might be 10 to 15 employees interested in taking SE courses at the beginning when such courses are offered at IUPUI, but the numbers may decrease after the initial demands were met. However, they also pointed out that if ISO would require certification on the industrial standards of ISO15288, then the demand for SE may see a tremendous surge.

XV. Describe the administrative structure of the certificate program.

Who is the designated program head?
What faculty are initially involved in the program (include their credentials)?
Describe any oversight or consulting committees overseeing the program.

The SE Certificate Program will be housed in the Department of Mechanical Engineering, but will be jointly offered by all the engineering departments within ENGT.

The Associate Dean for Graduate Programs at ENGT shall be the head of the program. The program will be administered by a Systems Engineering Graduate Committee (SEGC) with correspondingly broad representation. The Department Chair and Graduate Chair of the Department of Mechanical Engineering will be ex-officio members of the SEGC. The SEGC will have responsibility for decisions on Program and course content, admission of students, auditing, and certifying of completion.

A program code will be setup with the registrar's office for the purpose of admitting students. Upon a student's completion of the program, ENGT Graduate Office will notify Purdue Graduate School, who will issue the Graduate Certificate to the student.

The following faculty members will participate initially in the development of the program.

1. Hasan Akay, PhD, Professor of Mechanical Engineering
2. Jie Chen, PhD, Professor of Mechanical Engineering
3. Andrew Hsu, PhD, Professor of Mechanical Engineering
4. Anwar Sohel, PhD, Assistant Professor of Mechanical Engineering
5. Razi Nalim, PhD, Associate Professor of Mechanical Engineering
6. Yaobin Chen, PhD, Professor of Electrical Engineering
7. Stanley Chien, PhD, Professor of Electrical Engineering
8. Jose Ramos, PhD, Assistant Professor of Electrical Engineering
9. Sarah Koskie, PhD, Assistant Professor of Electrical Engineering
10. Edward Berbari, PhD, Professor of Biomedical Engineering

Appendix

Course descriptions of existing IUPUI courses

ME 575 Theory and Design of Control Systems (3 cr.) Class 3. P: consent of instructor. Modern control techniques, state space representations, performance evaluation, controllability, observability, and observer design are introduced. The Bond graph is developed as a versatile computer-aided method of modeling coupled systems.

ME 581 Numerical Methods in Mechanical Engineering (3 cr.) Class 3. P: 314, 372, and ENGR 197 or its equivalent. The solution to problems arising in mechanical engineering using numerical methods. Topics include nonlinear algebraic equations, sets of linear algebraic equations, eigenvalue problems, interpolation, curve fitting, ordinary differential equations, and partial differential equations. Applications include fluid mechanics, gas dynamics, heat and mass transfer, thermodynamics, vibrations, automatic control systems, kinematics, and design.

ME 597 Advanced Mechanical Engineering Projects I (1-6 cr.) Sem. 1 and 2. Summer Session. (May be repeated for credit). P: master's standing. Projects or special topics of contemporary importance or of special interest that are outside the scope of the standard graduate curriculum can be studied under the Mechanical Engineering Projects courses. Interested students should seek a faculty advisor by meeting with individual faculty members who work in their area of special interest and then prepare a brief description of the work to be undertaken in cooperation with the advisor.

ECE 536 Introduction to Computational Intelligence (3 cr.) Class 3. P: C programming skills; graduate standing or permission of instructor. Basic concepts in theory and paradigms for neural networks, evolutionary computation, and fuzzy logic; algorithms and applications for hybrids of these tools known as computational intelligence are explored. Topics include artificial neural networks, fuzzy systems, and evolutionary computation. Implementations of a number of paradigms are presented, including particle swarm optimization. Applications to various areas such as biomedical engineering and non-linear control are examined.

ECE 565 Computer Architecture (3 cr.) Class 3. P: 365 or graduate standing. An introduction to problems of designing and analyzing current machine architectures. Major topics include performance and cost analysis, pipeline processing, vector machines and numerical applications, hierarchical memory design, and multiprocessor architectures. A qualitative approach allowing a computer system designer to determine the extent to which a design goal is emphasized.

ECE 515 Software Engineering Methodology (3 cr.) Class 3. P: 359 or equivalent. Life-cycle models, software planning, software analysis, software design including data flow and data structure design, software testing methods, and software documentation. Software design project required.

ECE 580 Optimization Methods for Systems and Control (3 cr.) Class 3. P: consent of instructor or graduate standing. Introduction to optimization theory and methods, with applications in systems and control. Nonlinear unconstrained optimization, linear programming, nonlinear constrained optimization, various algorithms and search methods for optimizations, and their analysis. Examples from various engineering applications are given.

ECE 602 Lumped System Theory (3 cr.) Class 3. P: 301. P or C: MATH 511 or consent of instructor. An investigation of basic theory and techniques of modern system theory, emphasizing linear state model formulations of continuous- and discrete-time systems in the time and frequency domains. Coverage includes notion of linearity, time invariance, discrete- and continuous-times state models, canonical forms, associated transfer functions and impulse response models, the state transition matrix, the Jordan form, controllability, observability, and stability.

ECE 680 Modern Automatic Control (3 cr.) Class 3. P: 602 or consent of instructor. Theoretical methods in optimal control theory. Topics include the calculus of variations and the Pontryagin minimum principle with applications to minimum energy problems. Geometric methods will be applied to the solution of minimum time problems. Computational methods, singular problems, observer theory, and sufficient conditions for existence of solutions are also discussed.

STAT 511 Statistical Methods I (3 cr.) P: MATH 164. Descriptive statistics; elementary probability; random variables and their distributions; expectation; normal, binomial, Poisson, and hypergeometric distributions; sampling distributions; estimation and testing of hypotheses; one-way analysis of variance; correlation and regression.

STAT 512 Applied Regression Analysis (3 cr.) P: 511. Inference in simple and multiple linear regression, estimation of model parameters, testing and prediction. Residual analysis, diagnostics and remedial measures. Multicollinearity. Model building, stepwise and other model selection methods. Weighted least squares. Nonlinear regression. Models with qualitative independent variables. One-way analysis of variance. Orthogonal contrasts and multiple comparison tests. Use of existing statistical computing package.

STAT 514 Designs of Experiments (3 cr.) P: 512. Fundamentals, completely randomized design, randomized complete blocks. Latin squares, multiclassification, factorial, nested factorial, incomplete blocks, fractional replications, confounding, general mixed factorial, split-plot and optimum design. Use of existing statistical computing packages.

Course Descriptions of Proposed New Courses

SE 5xx Introduction to Systems Engineering Principles (3 cr.) P: graduate standing. Fundamental ideas of Systems Engineering, creation of diverse, complex engineered systems, defining system requirements, creating effective project teams. System life cycle and economics. Systems Engineering project.

SE 5xx System Modeling and Analysis (3 cr.) P: graduate standing. Architecture, behavior and optimization of systems. Design, simulation, optimization, and control of complex systems. Mathematical representation and computer modeling. Quantification of risk and model uncertainties. System modeling case studies

SE 5xx Systems Architecting
SE 5xx Project Management & Risk Analysis
SE 5xx Requirements Elicitation and Requirements Management
SE 5xx Human Factors in System Performance
SE 5xx Systems Financial and Contract Management
SE 5xx Health Care Management using Systems Engineering
SE 5xx Supply Chain, Logistics and Transportation Systems
SE 5xx Concurrent Engineering and Integrated Product Development Systems
SE 5xx Product Lifecycle Management