Developing a Multidisciplinary Engineering Program at Arizona State University East Campus

Chell A. Roberts, Albert McHenry
College of Technology and Applied Science,
Arizona State University Ease

Abstract

The purpose of this paper is to present an update on the planning of a new engineering program and Arizona State University (ASU) East. Planning began in the Summer 2003 and implementation is expected in 2005. This paper presents a background of Arizona Sate University East Campus and discusses the need for a new engineering program at ASU. A draft set of program requirements is presented along with some details for a new modeling and simulation concentration.

Background

In early 2003, Arizona State University (ASU) began the process planning a new department that will house a "general" engineering program. The new engineering program is anticipated to serve as a foundation for a polytechnic campus at ASU East Campus. ASU is a three-campus university serving the greater Phoenix area, with an enrollment of over 54,000 students. There are 46,000 students enrolled at the ASU Tempe Campus and 3500 students enrolled at the ASU East Campus.

Arizona State University East opened in the fall of 1996. The opportunity for the new campus was created with the closure of Williams Air Force Base in 1993, and an agreement to give the land to the State of Arizona. Currently the ASU East Campus consists of three colleges. The College Technology and Applied Science has programs in Aeronautical Management Technology, Information and Management Technology, Mechanical and Manufacturing Engineering Technology, Electronics and Computer Engineering Technology, and Computing Studies. The College of Agribusiness has programs in Professional Golf Mgmt, Pre-vet, Food Management, and Food Science. The East College has programs in Applied Psychology, Applied Biological Science, Business Administration, Elementary Education, Exercise and Wellness, Human Health, and Nutrition. ASU East has joined with Chandler-Gilbert Community College in an innovative New Partnership in Baccalaureate Education to offer complete ASU bachelors degrees, featuring small classes, an integrated curriculum, and cost savings for students. A Chandler-Gilbert Community College is collocated on the campus.

The Futon School of Engineering, with an undergraduate enrollment of 4700 students, is located on the ASU Tempe Campus. The Fulton School offers traditional discipline specific engineering degrees in electrical engineering, mechanical engineering, civil engineering, chemical engineering, material engineering, industrial engineering, bioengineering, construction engineering, and computer engineering. The Fulton School does not have capacity to increase overall enrollments. The Fulton strategic plan calls for a small decrease in undergraduate enrollments.

The planning for a new engineering program is a collaboration between faculties of the College of Technology and Applied Sciences (CTAS) at ASU East Campus and the Ira A. Fulton School of Engineering at ASU Tempe Campus, with support from the College of Education. It is envisioned that by dividing ASU engineering programs between two campuses the university will be better positioned to address the career goals of students and faculty. In addition, the development of a new engineering program developed from the ground up would provide a unique opportunity to develop and engineering program free from many of the structural constraints that make engineering education reform difficult.

The charge for the planning committee was to create an engineering program that would serve as a foundation for the polytechnic campus. A primary constraint was that the program should not duplicate degrees offered by the Fulton School. At the writing of this paper the planning of the program continues. A Director of planning has been hired. No other faculty members of the new department have been employed. The implementation of the program is targeted for early 2005. This paper presents the results of the planning effort to date. The paper discusses the need for a new program, models of general engineering programs, a preliminary program plan, and a presentation of the planned concentration in modeling and simulation.

The National, Regional, and State Engineering Need

The national need for increasing the number of engineering graduates is uncertain. A jobless economic recovery, the movement of many manufacturing operations offshore, and an increase in out-sourced services fuel this uncertainty. Some studies support the national need for increasing the number of qualified engineers. The ACT Office of Policy Research states that the US position as a world-engineering leader is threatened by a dwindling number of qualified engineering students[1]. The U.S. Commission on National Security[2] recommends: "the American educational system needs to produce significantly more scientists and engineers …". However, A draft paper from project on the economics of advanced training at National Bureau of Economic Research[19] raises questions about any predicted shortages of engineers.

The state of Arizona has established a plan to increase its high-tech economy that includes increasing the number of science and engineering graduates[14,15,16,17,18]. Arizona's population increased 93% from 1989 to 2001. As a result, Arizona is one of the highest growth states in the number of high school graduates. It is projected that there will be 5,947,000 Arizona Residents by 2008 and 8,305,000 Arizona Residents by 2020. At about that time the population of the Phoenix metropolitan area will be roughly the same size as London and will be served by one local university, ASU.

The demand for undergraduate engineering education at ASU has also been steadily increasing for more than a decade. A forecast of the overall enrollment demand for all undergraduate engineering programs at ASU, based on enrollment data from 1989 to the 2003 projects a 26% enrollment increase by 2008, representing an increase of more than 1200 students. This represents an enrollment opportunity for the new program since the Fulton School plans a reduction in undergraduate engineering enrollments.

A New General Engineering Program

The new engineering department and program will offer a Bachelor of Science (BS) in engineering degree and will seek accreditation through the Accreditation Board for Engineering and Technology, Inc. under the general engineering criteria. A semi-flexible general engineering model is the most likely implementation. The department will reside in the College of Technology and Applied Science and will not be part of the Fulton School. It is believed that structural separation from the Fulton School will provide autonomy from many constraints that would hinder the development of new engineering program from a clean slate. The engineering program will also serve as a foundation for the creation of a polytechnic campus. Polytechnic schools share an emphasis on professional, career-oriented academic programs as their core mission, with particular strength in highly technological fields such as engineering and technology. As part of the planning process, models of other general engineering programs were examined.

There are a small but growing number of accredited general engineering programs in the US. The current tally is 33 accredited "general" engineering programs. Most of these programs do not use the title "general", but are referred to as general engineering programs because they are accredited under the general ABET criteria for engineering. There are 22 accredited general engineering programs at private universities and 11 accredited general engineering programs at public universities. The vast majority of general engineering programs at public universities are found on "secondary" state campuses.

A recent study by Newberry and Farison [17] suggests a taxonomy of general engineering models. The following model description is an adaptation of this taxonomy. There are four general engineering models that have been implemented nationally. Historically, many schools adopt a general engineering model as a transition to discipline specific programs (**instrumental model**). These programs tend to have a fixed curriculum that offers discipline specific concentrations similar to traditional disciplines (e.g. Arkansas State University and Montana Tech). There are 18 accredited instrumental model programs (13 private, 5 Public). Some of these programs remain small and do not transition to discipline specific programs.

Some general engineering programs have been developed to provide greater flexibility (**flexible model**) for students. The more extreme flexible models permit student to design some of their own program (e.g. Purdue or Olin College), though these programs have a more difficult time achieving accreditations and have smaller enrollments and graduation rates. Another type of flexible model (**semi-flexible**) offers flexibility through the choice of a minor or a secondary concentration (e.g. Illinois). Some programs offer flexibility by offering a greater number of elective hours (e.g. Baylor and Michigan Tech). There are 10 accredited flexible model programs (4 private 6 public). An alternative general engineering model (**philosophical model**) provides students with engineering breadth and a high level of liberal arts content (e.g. Harvey Mudd, Swathmore, Hope, and Dartmouth). There are four accredited philosophical model general engineering programs. All of these are housed at private universities.

Many universities implement engineering models that are not intended to be accredited. Some flexible programs such as the interdisciplinary program at Purdue, the BA Engineering program at the U of A, and the "general" engineering program at Cal Poly do not intend to be accredited. Another typical model in this category is the **core model** where a department or program offers only core engineering courses (e.g. Penn State and Virginia Tech). Students do not graduate from these programs but go on to other discipline specific programs.

Queries were sent to all accredited general engineering program regarding enrollment, graduation, and faculty demographics. The average enrollment of 14 programs that responded to demographic inquiries was 261 with an average annual graduation of 61 students. The average student/faculty ration was 23:1. The largest program is at Colorado School of Mines with just over 1000 BS students. The next largest program is the University of Illinois with 562 students. Table 3 shows the demographics of the seven largest general engineering programs in the US based on the available responses. It is not clear from the data if the student and faculty numbers represent full-time equivalents.

Table 1 Demographics of Selected General Engineering Programs

School	Type	Model	Annual Graduates	Student Enrollment	Faculty
Colorado School of Mines	Public	Semi- flexible	300	1000	24
University of Illinois	Public	Semi- flexible	62	562	22
Mercer	Private	Instrumental	60	450	32
McNeese	Public	Instrumental	18	389	16
Calvin	Private	?	70	350	13
Arkansas State	Public	Instrumental	35	300	13
Harvey Mudd	Private	Philosophical semi-fixed,	70	150[#]	20

Students admitted to engineering late in sophomore year. Size closer to a 300-student program.

The large general engineering programs have all been in existence for more than 10 years. The general engineering model however is new to Arizona industry. Industry focus groups indicate that much of the hiring is done by discipline oriented departments. Student focus groups indicate that they are not familiar with the general engineering model.

Draft Program Requirements
The new engineering program will require a total of 120 credit hours, including at least 50 hours of upper division course work. Within the 120 hours students must meet University General Studies requirements and major prerequisite requirements, totaling 56 hours. They will also take 22 hours of engineering professional requirements that represent a core for all engineering students. Students will also select a primary and secondary concentration of 15 hours each. One of these concentrations may be student designed. There will be a three-hour design clinic in both the sophomore and junior years and a two-semester capstone clinic in the senior year. A student must take one of the design clinics in each concentration area. Table 2 presents a draft of the program requirements and table 3 presents a more detailed presentation of the requirements.

Table 2. Program Requirements Overview

Program Requirements	**CH**
General Studies/FYC	42
Addtl major prerequisites	14
Engineering Professional Requirements	22
Concentration Coursework	30
Design Clinics	12
Minimum Total Credit Hours	120

Table 3. Detailed Program Requirements

	CH
English Proficiency (6 Hours)	6
Social/Behavioral Sciences (15 Hours)	15
Literacy / Critical Inquiry (6 Hours)	6
Natural Sciences/Basic Sciences (11 Hours)	
CHM113 General Chemistry OR CHM114 General Chemistry for Engineers	4
PHY Engineering Physics	3
PHY Engineering Physics Laboratory	1
GEG180 Biology for Engineers	3
Mathematics Studies (18 Hours)	
ECE 380 Engineering Statistics (CS)	3
MAT 270 Calculus with Analytic Geometry I	4
MAT 271 Calculus with Analytic Geometry II	4
MAT 272 Calculus with Analytic Geometry III	4

MAT 274 Elementary Differential Equations	3
Engineering Professional Practice (22 Hours)	
GEG 100 Introduction to Engineering Design (CS)	3
GEG 201 Conservation Principles	3
GEG 202 Dynamical Engineering Systems	3
GEG 203 Continuum Engineering Systems	3
GEG 205 Foundations of Business and Entrepreneurship	3
GEG 250 Structure and Properties of Materials	3
GEG 260 Not Yet Determined	4
Concentrations and Design (42 hours)	
GEG290 Sophomore Design	3
GEG390 Junior Design	3
GEG490 –GEG491 Senior Design	6
Primary Concentration	15
Secondary Concentration	15

Currently there are draft plans for concentrations in Modeling and Simulation, Security Engineering, Business and Entrepreneurial Systems, Digital Electrical Systems, and Mechanical and Automation Engineering. More concentrations will be added as the program grows. The next section discusses the modeling and simulation concentration.

The Simulation Engineering Concentration

The need for an undergraduate Modeling and Simulation (M&S) program today is compelling and motivated by three key factors. First, given that technology is galloping at an incredible rate, the inherent interdisciplinary nature of M&S fosters a much-needed cross-disciplinary perspective in M&S engineers. Second, the absence of professionals trained in M&S is keenly felt in diverse enterprises: in the U.S. Military that is committed to network-centric warfare under the new Future Combat System program; by the financial services industry that is dependent on the computing and networking infrastructure; by the Homeland Defense department that must develop and test unprecedented architectures to defeat attacks by intelligent and dedicated terrorists; and in the industry in general that is increasingly becoming dependent on complex networked systems. Third, M&S' holds incredible promise to open new technological frontiers in disciplines such as simulation-based drug design and testing, examining the life cycle of a viral or bacterial epidemic through simulation, or understanding the construction and organization of the biological brain (humans, dolphins, squid, etc).

Over the past several years the simulation community has increasingly called for the development of M&S degree programs. Some argue[13] that an M&S program should be accredited, that the appropriate discipline is engineering due to the widespread use of simulation in engineering, and that the ideal career development path for professional practice should begin with the Bachelorette degree as preparation for professional practice. "The ideal professional (e.g., Electrical Engineer or an architect) is educated by obtaining an initial professional education (generally Bachelorette Degree), receiving on-the-job training and experience (skill development), obtaining license or certificate, exercising code of ethics, and continual professional development. Within some professions (e.g., M&S) government and commercial entities (Defense Modeling and

Simulation Organization, Aegis Technologies, Cisco, Sun Micro-systems, and Rational to name a few) offer short courses and alike to educate student/professionals about their standards, tools, and methodologies. Henceforth, academic institutions, employers (e.g., industry), professional societies (e.g., ACM and IEEE), and commercial entities collectively realize the necessary infrastructure in the creation of M&S professionals[13] Other researchers have concluded that a curriculum background in either science or engineering is essential for simulation education[6,9,10].

Creating an M&S program within an accredited traditional discipline specific engineering undergraduate program (e.g. Electrical or Mechanical Engineering) would be challenging since disciplinary requirements typically leave very few technical electives to the student. A new program could be created within an existing department, but a clear path to accreditation would likely be required for institutional approval; identifying the best traditional disciplined engineering department to house the new program would also be difficult since M&S is inherently interdisciplinary. It would also be possible to develop a simulation program as an interdisciplinary engineering program at the undergraduate level. However, interdisciplinary programs generally pose administrative and accreditation challenges as faculty and resources have an ambiguous relationship to the interdisciplinary program. A greater degree of flexibility in the accreditation criteria for general engineering strongly facilitates the development of a program for this new emerging discipline.

The knowledge base in the area of simulation has been continuously growing for decades. Nance and Balci[5] have identified 13 distinct types of simulation. Any detailed coverage of all of these areas would be prohibitive at the Bachelorette level. Roberts and Gosh[8] suggest an approach to developing an accredited undergraduate M&S degree program. Fujimoto[3] suggests seven guiding principles for M&S programs. These are:

1. A solid grounding in fundamentals is essential.
2. Basic knowledge and skills in computing fundamentals are important.
3. Tight coupling with application domains must be maintained.
4. Exposure of students to a broad range of core M&S topics is essential.
5. Fluency in multiple modeling paradigms is a key to intellectual development.
6. Students should understand the full M&S life cycle.
7. Effective communication skills are a prerequisite for success.

Professional certification and undergraduate engineering education are closely related. Much of the undergraduate engineering core for many institutions is consistent with the professional engineering fundamentals examination. Likewise, a simulation curriculum can be guided by the professional simulation certification examinations offered by The Modeling and Simulation Professional Certification Commission[4].

The necessary elements in an M&S program can be organized into a three-level tiered structure. The innermost core constitutes the first stage of the program, spreading over 1-2 years, and is intended to impart expertise in modeling real-world and abstract processes. The middle core represents the intermediate stage, spanning a year, where students are exposed to the fundamental principles of simulation. The final stage allows students to specialize in any of the areas of their choice and includes a major project that must incorporate design, implementation, and testing, and demonstrate the student's mastery, depth-wise and breadth-wise in modeling and simulation.

The innermost core will provide the principles of modeling, especially logical behavior, causality, and timing; the medium through which executable models may be expressed, namely general-purpose and special-purpose programming languages; and the fundamental knowledge pieces from physics, mathematics, chemistry, biology, medicine, law, social behavior, business, and finance. The intent is for the knowledge pieces to assume the form of highly condensed rules, laws, core principles, and insights, and to provide students a unique ability to move freely across different disciplines as they progress in their careers. The middle core will include the topics of centralized and synchronous simulation, discrete event specification systems (DEVS), generalized DEVS (GDEVS), asynchronous distributed simulation, and stochastic variables. In their final year, M&S students may specialize in a number of areas including digital systems design, fault simulation and testing of VLSI, video game design, simulation of activities in outer space, automobile design and testing, net-centric warfare in the military, accelerated drug testing in the medical and pharmaceutical industry, harbor management and security, intelligent transportation, financial services systems, and others. The list of specialization areas will inevitably grow with time. ASU and The Society for Modeling and Simulation (SCS) plan develop a curricular plan that addresses the three-tiered structure in a comprehensive manner to serve both as a guide and an accreditation standard.

Rogers[9] identified the basic knowledge and skills needed by an M&S professional as:

1. Good analytical skills in probability and statistics, experimental design, and stochastic methods.
2. Computational Competence
3. Mathematics and Operations Research
4. Project Management Skills
5. Cost Modeling
6. A Foundation in Physical Sciences
7. An Understanding and Appreciation for the Scientific Method.

Most of these skills are general to engineering and will be attained by students taking a general engineering core. Knowledge and skills in the areas of experimental design, stochastic methods, operations research, and cost modeling will need to be developed. In addition to the basic knowledge and skills, content that helps develop specific knowledge and skills in simulation related to problem identification, data gathering and analysis, simulation modeling and methods, simulation output analysis and validation, standards, and domain specific applications will need to be developed in the full implementation.

The current plan includes the development of modules (one to two hours each) that should provide greater flexibility for infusing simulation into the curriculum at appropriate points (e.g. a one hour simulation using physics engines in conjunction with a physics course). Modules that will be developed include: Simulation using Physics

Engines, An Overview of Simulation Engineering, Monte Carlo Simulation, Interoperability Standards, HLA Architecture, Simulation Methods and Modeling, Simulation Output Analysis, Simulation Validation and Verification, Stochastic Models, Deterministic Models, Security Systems Simulation, Cost Modeling, Cost Engineering, Simulation Languages, Data Collection for Model Building, Identifying Simulation Variables and Parameters, Continuous Simulation Models for Engineering, Control Modeling, Hybrid Systems, Human Computer Interface and Visualization, Simulation Applications in Bioengineering, Simulation Applications in Electrical Engineering, Simulation Applications in Mechanical Engineering, and Simulation Applications in Social Systems. As an example of one of the modules, the Simulation using Physics Engines, the Overview of Simulation Engineering, and the Monte Carlo modules are described.

Simulation Modules

There are several physics engines for simulation in areas such as particle dynamics, smoke, mechanical systems, and biomechanics. These engines are often used in gaming environments and are more frequently becoming simulation engines for industrial applications. A one or two hour module in physics simulation will be developed and offered as an augmentation to the traditional physics sequence. The focus will be on inquiry-based learning of physics using simulations. In this module students will also learn to parameterize simulation models and will have at least one open-ended problem-based simulation opportunity. We plan on using the MathWorks engine for the module.

The overview module will explore the broad spectrum of simulation applications and simulators currently used today. The course will also explore the simulation engineering profession, including the simulation code of ethics and simulation certification options. The breadth of simulation applications could include the simulation of nuclear, bio, business, and nano systems; interactive simulation environments; vehicle simulation; and simulation for analysis of designed mechanical, electrical, industrial, and social systems. Training simulators such as flight simulators, nuclear training simulators, and power plant simulators will also be explored.

The Monte Carlo module will introduce students to the central concepts of Monte Carlo simulation. Possible topics in this module include probability and random number generation; Monte Carlo techniques for numerical computation and approximation; Monte Carlo optimization techniques including simulated annealing, genetic algorithms, and stochastic approximation; and performance characterization of complex engineered systems. All of these topics will be developed for a problem-based learning environment in the context of real engineering problems. Potential application areas include characterization and control of complex nonlinear dynamical systems (e.g. biological, social, economic, molecular, or quantum-mechanical systems); inference of information and structure from data (e.g. data mining, bio-informatics, or military or civilian sensor networks); and optimization (e.g. process control, protein folding, or risk mitigation). These application areas provide a rich variety of options for projects and supplemental course materials.

Some Concluding Comments

This paper has presented a draft plan for the implementation of a new general engineering program at ASU East. The plan calls for the implementation of a semi-flexible general engineering model with a requirement for a primary and a secondary concentration. Several concentrations have been identified for implementation, including a concentration in modeling and simulation. The planning process is still underway and will likely result in many changes to the current draft plan of a new engineering program. The hiring of a core group of faculty to develop the new program is underway, and will influence the final concentrations developed.

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Author Biographies

Chell A. Roberts, Ph.D., is the recently named Director of Engineering programs, CTAS. He has served ASU Main Fulton School of Engineering as an associate professor of industrial engineering and chair of that department's graduate program. He currently serves as a member of the board of directors for the Society for Computer Simulation and has been active in developing undergraduate engineering design curriculum.