PROGRAM DESCRIPTION AND CHARTER

For The

INTERDISCIPLINARY GRADUATE PROGRAM

In

SYSTEMS ENGINEERING

July 1996

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FOREWORD

This Program Description and Charter consolidate into one document the essential academic and programmatic characteristics of the interdisciplinary graduate program in Systems Engineering. A charter became necessary due to the administrative and fiscal shift of the program from the Office of the Dean of Engineering to the Department of Industrial and Systems Engineering (ISE) beginning with Academic Year 1995-96.

The administrative and fiscal shift of Systems Engineering (SE) to ISE will not have a detrimental effect on the time-tested academic structure and programmatic character of Systems Engineering at Virginia Tech. Its academic intent and program characteristics will continue to be guided by the Systems Engineering Advisory Committee (SEAC) of the College of Engineering. However, ISE has full administrative and fiscal responsibility for all resources necessary for program support (space, purchasing, travel, support staff, etc.). Admittedly, there may be some issues that will not fall nicely into either the administrative/fiscal or the academic/programmatic domains. Additionally, an appropriate balance must be maintained between support resources and program needs.

The Systems Engineering Graduate Program will continue to be a product of the College of Engineering acting as an entity, with each participating department playing an appropriate role. Systems Engineering is offered in accordance with a paradigm that has finally attracted widespread attention internationally. Virginia Tech is in the lead and is often used as an example of what could occur in colleges of engineering elsewhere. Accordingly, for the record and as a benchmark for considering suggested improvements, this document summarizes the inherent nature and administration of the Systems Engineering graduate program.

ARTICLE I. NAME AND PURPOSE

Section 1. Name

This interdisciplinary graduate program is known as "Systems Engineering," and is offered only at the masters-degree level by the College of Engineering, Virginia Polytechnic Institute and State University (commonly known as Virginia Tech). Upon successful completion of degree requirements, a student may receive a Master of Science in Systems Engineering (thesis option), Master of Science in Systems Engineering (non-thesis option), or Master of Engineering in Systems Engineering. The acronym for this program is **SYST**.

Section 2. Purpose

Systems Engineering is the application of scientific and engineering efforts to transform an operational need into a defined system configuration through the iterative process of design, test, and evaluation. It involves the integration of many different engineering specialties into a *total* engineering effort, resulting in an efficient and effective product output. A major aspect of

Systems Engineering is a concern for the overall life cycle of a system; i.e., planning, design and development, test and evaluation, production and construction, utilization (operations), maintenance and support, and system retirement. Thus, Systems Engineering is broad in nature involving the process of bringing systems into being with consideration given to all phases of the system life cycle. It is *interdisciplinary* and should not be viewed in the same context as one of the traditional engineering disciplines.

Within this broad spectrum, there are many categories of systems in use today. Further, the complexities of design, production and/or construction, operation, and the support of each can vary significantly. The development of systems requires a *team* approach, often involving several different engineering disciplines. A systems engineer is one who can (1) understand the process of brining systems into being; (2) identify and define various components of the system; (3) define and cause the concurrent integration of the various engineering disciplines involved in system development; and (4) understand the sustaining operation and maintenance support requirements throughout the consumer use period. The systems engineer must understand the interdisciplinary aspects of system development, operation, and support.

ARTICLE II. BACKGROUND

Section 1. Origin and Historical Sketch

The interdisciplinary program in Systems Engineering traces its origin to action taken by the Virginia Tech Board of Visitors in November of 1968. Based on the recommendation of the engineering faculty, a two-dimensional grid-type structure was established within the College involving the ten engineering departments (i.e., the traditional engineering disciplines), augmented by five "Technical Interest Groups (TIGs)" cutting across departmental lines. These groups directed their attention to interdisciplinary programs of graduate study, research, and extension. The Systems Engineering program was established as one of these TIGs. Initial planning for graduate study in this area began in 1969, and the State Council for Higher Education in Virginia (SCHEV) approved the MS and ME degree programs in 1971.

The first degree in Systems Engineering (MS with thesis) was awarded on the campus in Blacksburg, in 1972. During the 1970s, the program expanded slowly with a few full-time on-campus students plus an increasing number of part-time off-campus students. The largest area of growth occurred off-campus, particularly in Northern Virginia. By the mid 1980s, the program became very popular and significant additional growth was experienced. One reason stems from the increased emphasis on "Systems Engineering" being adopted in industrial and government organizations throughout Virginia. This, combined with the high degree of "flexibility" offered within the program structure, resulted in a great deal of interest.

There are over 250 part-time off-campus individuals and about a dozen on-campus students in the program. The off-campus segment continues to grow with the popularity of systems engineering, and the on-campus segment includes a few who are on a long-term

"education/training leave" from their organizations. All individuals in the program have had some industrial/government experience and are interested in the program because of its interdisciplinary character. Thus far, there has been no attempt to recruit undergraduate students directly into the program, as it is believed that one should have some practical experience prior to entering into the field. Through AY 1995-1996, over 300 received a Masters degree in Systems Engineering, with 30 to 35 graduating in each of the past seven years.

Section 2. Student Characteristics

The graduate program in Systems Engineering was fashioned primarily to allow engineering practitioners in specialized fields (e.g., civil, engineering, electrical engineering, mechanical engineering) to pursue an interdisciplinary approach to engineering. It is desired that individuals entering the program have a solid foundation in some specialized field of engineering (or equivalent) and wish to broaden their knowledge base. Accordingly, the program is structured to allow individuals to pursue a chosen systems area of specialty, while also selecting design oriented courses of interest in other specialty areas. There are three required courses that provide the tools for integrating these various specialties utilizing a **systems approach**. The objective is to allow students to "tailor" their respective plans of study in response to individual needs.

Students in the program fall into two basic categories:

1. **Full-Time On-Campus Students in Blacksburg**. Each year, there are from 10 to 20 full-time students enrolled in the program on the campus in Blacksburg. While the majority are pursuing the Master of Science degree (non-thesis option), there are a few who choose to pursue the thesis option and are involved in funded research activity. The on-campus students primarily include those who have been employed in industry/government, are on a "long-term training" leave, and are funded by their sponsoring organizations. These students follow the same procedures relative to application, processing, registration, etc., as apply to any other graduate student on the Blacksburg campus. They are advised and receive support from the Systems Engineering Program Office, and have the use of the Systems Engineering Design Laboratory (SEDL) to support their academic study and research.

2. **Part-Time Off-Campus Students**. There are over 250 part-time students located throughout the State of Virginia and at a few selected out-of-state sites. This off-campus segment of the program continues to grow, and there are many different student "patterns." To provide a better understanding of the off-campus environment, in general, the following assumptions should be noted:

(a) An individual may apply for the program at **any time** during the year, may register and take one course (as a "Commonwealth Campus Program" student) while the student's application materials are being processed. When formally accepted into the program as an approved graduate student he/she may continue to pursue courses at their own pace. Providing the necessary

courses that will allow a student to follow a "fixed" plan of study in a designated time frame has been found to be impossible.

(b) Students in the program set their own rate in completing courses. The majority will take one course per semester and continue along at a steady rate; some will take two courses per semester if their job and family schedules will permit; and there are a few who are on a "long-term training" leave, living at home, and who are pursuing up to four courses per semester. Students will skip a semester if their work schedules become too demanding, or if there is a family issue that requires their full attention. Some will finish their program requirements within the preferred five-year time period specified by the Graduate School, and some will drop out for awhile and then apply for re-admission later. The off-campus student population is highly "dynamic." At the same time, the objective is to provide enough courses that will allow a student to complete a plan of study, on a continuing basis, and at his/her own rate.

(c) The experiences and individual academic backgrounds of the off-campus students may vary significantly from one person to the next. While a general prerequisite to being admitted into the program is the completion of an undergraduate degree in some field of engineering (or equivalent), there are students from a variety of disciplines desiring courses in different fields and pursuing a maters degree in systems engineering. Accordingly, there must be enough courses available that will allow for a student to pursue his/her desired area of concentration in a timely manner.

In offering an academic program, it is essential that the University thoroughly understand the market and the environment in which the student must operate. The systems engineering program is responsive to both on-campus and off-campus needs, primarily because of the flexibility that has been incorporated.

ARTICLE III. PROGRAM STRUCTURE

Section 1. Academic Program Structure

A minimum of 30 semester credit hours is required for a master's degree in Systems Engineering. Each student's plan of study must include two required core courses, four courses in a selected area of concentration, two courses in a different area of engineering or one course in each of two other areas, one course in a non-engineering area, and a project report (or thesis for a "research" focus). More specifically, the course requirements include:

1. **ENGR 5004, The Systems Engineering Process.** Development and implementation of the systems engineering process, beginning with the identification of system-level requirements (i.e., a consumer need) and extending through functional analysis and requirements allocation, synthesis, trade-offs and design optimization, selection of a specific configuration, test and evaluation, construction and production, utilization, maintenance and support, and system retirement. The process includes the integration of performance factors, reliability,

maintainability, human factors, logistic support, producibility, disposability, life-cycle cost, and other factors essential in the development of a system. This course is "process-oriented" and provides a foundation for a student's plan of study (and course selection. A group project is included to facilitate a student's understanding of the system engineering process. (Three credit hours).

2. **ENGR 5104, Applied Systems Engineering.** Development of a working knowledge of systems engineering by solving problems involving technology in the context of the society and environment in which they exist. Specific objectives are (a) to define systems engineering in the context of "systems thinking;" (b) to show how this systems approach can be used to structure knowledge so as to provide a foundation upon which new knowledge can be added, as well as permitting the transfer of understanding between disciplines; and (c) to improve our problem solving abilities by modeling these problems mathematically. This course makes use of three forms of modeling — verbal, graphical, and mathematical. Starting with verbal descriptions of problems, the relationships between key variables are displayed in "causal diagrams" which are easily expressed in the form of mathematical equations. The models are solved both analytically and using computer simulation. The "system dynamics" methodology developed at M.I.T. is used as a guide. The objective is to demonstrate the application of analytical methods within the context of the systems engineering process (in three credit hours).

3. **Concentration Area Courses**. At least 12 credit hours must be selected from the "systems oriented" courses in a chosen engineering specialty area. These areas include aerospace and ocean engineering, chemical engineering, civil engineering, electrical engineering, industrial and systems engineering, and mechanical engineering. These courses should be "design-oriented" and complementary with the material covered in ENGR 5004. The student's area of concentration is usually selected based on a combination of his/her academic background and experience, and provides a "focus" for the selection of a final Project Report (ENGR 5904) topic and academic advisor for the project activity.

4. **Other Engineering Courses**. At least six credit hours must be taken in one or more engineering specialties outside of a student's area of concentration. The selected courses are intended to provide a truly **interdisciplinary** thrust within a given student's plan of study (not only with regard to course content but also through the interaction with faculty from different disciplines).

5. **Non-Engineering Course(s).** At least three credit hours must be taken in appropriate non-engineering disciplines. Elective courses may be selected from business, computer science, economics, mathematics, statistics, or related. The selected course(s) should provide some of the tools necessary to support the engineering specialty courses above.

6. **ENGR 5904, Project and Report**. For the Master of Science degree (non-thesis option) and the Master of Engineering degree, each student must undertake project work and prepare a formal project report. The project report, usually completed as the final program requirement, is

presented as part of the student's final examination, defended before his/her academic program committee of three, signed off, and processed for binding through the Graduate School. Approved bounded copies of the report are included in the University Library and in the Systems Engineering Library. (Three credit hours).

The topic selected for study should be technical in nature (engineering-oriented versus a business or administrative orientation), addressing a defined "problem," and usually related to some issue within the bounds of the student's area of concentration. While the thrust of the project is of an in-depth technical nature, the material should be presented within the context of the system engineering process as introduced in ENGR 5004. The objective is to apply some of the methods and tools of systems engineering.

7. **ENGR 5994 (or Dept. Designation), Research and Thesis**. For the Master of Science degree, with a research thrust, a thesis is required in lieu of the Project and Report (ENGR 5904). This generally applies to students studying on the Virginia Tech campus in Blacksburg who are pursuing research and graduate study under the day-by-day direction of a faculty advisor. The thesis requirement is in addition to the **nine** required courses in the systems engineering program, and is in compliance with the general guidelines specified by the Graduate School.

8. **Final Examination**. The final examination for the systems engineering degree includes the student's defense of the Project Report (ENGR 5904) or Thesis (ENGR/XXX 5994) before his/her program academic committee, and is usually conducted during the final semester of study. In addition, the student must be prepared to answer any questions pertaining to academic course work that may be posed by a committee member. The final exam is conducted in accordance with Graduate School policies and procedures.

Section 2. Research and Public Service

Inherent within any graduate academic program is the need of pursue both basic and applied research and to disseminate results to interested publics. The objectives of research and public service are to:

1. Promote the discipline of Systems Engineering through study and the development of methods, tools, and/or processes to enhance the application of the basic principles conveyed in ENGR 5004, ENGR 5104, and systems courses. The objective is to further strengthen the discipline internationally, and to enhance Virginia Tech's position as a leader in the field. This can be facilitated partially through active participation in such organizations as the International Council On Systems Engineering (INCOSE).

2. Determine the needs of businesses, industries, and government agencies located within the State of Virginia relative to the potential application of systems engineering methods/tools to aid in responding to current problems of system design and development.

3. Establish the appropriate collaboration with selected businesses, industries, and/or government agencies, and provide assistance as necessary in the application of system engineering principles and methods to enhance their operations and productivity.

4. Disseminate the results of research to practicing professionals in the field and to the students enrolled in the Systems Engineering graduate program.

Section 3. Systems Engineering Design Laboratory

The Systems Engineering Design Laboratory (SEDL), serves as a focal point for the pursuit of research activities in the field. As a secondary mission, it provides direct support to the academic and instructional activities within the program; i.e., the appropriate computers (DOS or UNIX-base systems), networks, mainframe computer connection, printers, etc. The Laboratory is also connected to the Virginia Tech campus-wide television network, providing direct access to academic courses being offered via satellite transmission through the Virginia Commonwealth Graduate Engineering Program (CGEP). Both ENGR 5004 and ENGR 5104 are offered annually via this method of delivery, and the Laboratory provides a medium for receiving these courses directly and for conducting discussion groups and related presentations in the subject area.

ARTICLE IV. ADVISORY COMMITTEES

Section 1. SE Program Advisory Committee

The figure below presents the System Engineering Program within the context of the College of Engineering organization. To promulgate its **interdisciplinary** nature, program direction comes from an "SE Program Advisory Committee," organized at the College level. This includes the establishment of program requirements pertaining to academic content (i.e., course selection, admissions criteria, student plans of study, project/thesis guidelines, final examinations/defenses, and exit criteria). This Committee meets at least once each semester and is responsible not only to ensure that all academic requirements are met, but to provide on-going surveillance and evaluation of program output and effectiveness relative to resources allocated.

The SE Program Advisory Committee shall consist of six members of the engineering faculty, one from each of the participating engineering disciplines. The faculty selected for these positions are appointed by the appropriate academic Department Head, and shall continue to serve on the committee until such time as he/she retired or desires to be replaced. Each active member of the committee shall have a designated "assistant," representing his/her department.

The members of the SE Program Advisory Committee, as a group, will identified candidates, conduct the appropriate interviews, and nominate a faculty member for the position of "Systems Engineering Program Chairperson." The nomination shall be submitted to the Associate Dean for Research and Graduate Studies who, with the Dean of Engineering, will review and select the person for the position. The appointment will be for a period not to exceed five years.

Candidates for this position shall be tenured and have the academic rank of Associate Professor (or higher), and be appointed to a Calendar-Year (CY) position. He/she will serve as the program director, will be responsible for the day-to-day operations of the program, and will ensure that the objectives of the program are met. The Program Chairperson will work closely with the Academic Advisory Committee Chairperson relative to matters of an academic and programmatic nature, and with the ISE Department Head in matters of an administrative and fiscal nature.

The makeup of the SE Program Advisory Committee includes the Program Chair and a faculty representative from each of the participating engineering disciplines (i.e., Aerospace and Ocean Engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Industrial and Systems Engineering, and Mechanical Engineering). The Associate Dean of Engineering for Research and Graduate Studies participants in an "ex-officio."

Section 2. Student Advisory Committees

The student's academic advisory committee constitutes three individuals, with at least two being from the Virginia Tech Faculty. The third individual may be selected from outside (industry, government agency, or equivalent). The Committee Chair must be a full-time member of the faculty, usually representing the engineering discipline constituting the student's area of concentration.

The student is responsible for the formation of his/her committee. In pursuing an area of concentration for course selection, the student will select a topic for research and study, identify a faculty member who conducted a class in this area (usually one of the courses selected), prepare a proposal for his/her ENGR 5904 or ENGR/XXX 5994, and solicit the assistance of the faculty member and his/her willingness to serve as Chairperson of that committee. The student will work with the faculty member in the development of the project report or thesis. Members of the SE Program Advisory Committee may be requested to aid a student in selecting a Chairperson.

Additionally, the student will be required to identify and approach two other qualified individuals to serve on his/her committee. At least one of these individuals must be a full-time member of the Virginia Tech faculty. The other can be a representative of industry, a government agency, or equivalent, as long as there is no conflict of interest relative to inhibiting the student from pursuing the area of research desired. The committee should be interdisciplinary.

ARTICLE V. PROGRAM ADMINISTRATION

Section 1. Graduate School Requirements

Virginia Tech's Systems Engineering graduate curriculum, leading to the M. ENGR. and M. S. degrees, was approved 25 years ago by the State Council for Higher Education in Virginia

(SCHEV). It conforms to Graduate School policies and requirements and has withstood the test of time.

The requirements for admission to the program, student processing, and graduation shall be in accordance with the policies and procedures of the University Graduate School, the College of Engineering, and those specific for the program concentration as noted in the program structure in ARTICLE III.

Section 2 College and Departmental Requirements

From a curriculum perspective, SE is shaped by three coordinated influences. First, there are the Graduate School requirements for graduate study. These general requirements are augmented by interdisciplinary program structure requirements and promulgated through the SEAC. Departmental requirements follow and are rightfully of concern to the graduate curriculum committees of the participating departments. Participating departments are represented on the SEAC to help monitor overall program structure and quality, and to provide feedback for program review and improvement.

After two core courses (ENGR 5004 - The Systems Engineering Process and ENGR 5104 - Applied Systems Engineering) degree candidates fashion plans of study invoking graduate courses from a minimum of two engineering departments and one non-engineering discipline. Of particular note is the requirement that four courses be chosen from the systems oriented offerings of the host or home department. This focus, coupled with ENGR 5904 - Project and Report, gives ample opportunity for the home department to tailor and influence the student's SE orientation. Accordingly, at least one-half of the degree program requirements are controlled by the participating department. This half is rightfully addressed and promulgated by the faculty and curriculum committee of the home department.

While matters of an academic nature are addressed by the College-level committee, administrative and fiscal provided through the Industrial and Systems Engineering Department. This includes budgetary support, office and laboratory supplies, computers and related equipment, communication services (telephone, fax), and personnel requirements (secretarial and student assistance). The Systems Engineering Design Laboratory (SEDL) is operated through the ISE Department.

Section 3. Student Advising and Plans of Study

The day-to-day student advising shall be the responsibility of the Program Chairperson. He/she may solicit assistance from one (or more) members of the Academic Advisory Committee on an as-required basis. Individual student plans of study will be reviewed and approved by the Program Chairperson.

Section 4. Final Examination

Each student must successfully pass a final examination consisting of two parts. First, the student must schedule and successfully defend his/her Project Report (ENGR 5904) or Thesis (ENGR/XXX 5994), whichever the case, before the committee of three. After the student has prepared a completed "draft" of his/her document, and is considered to be ready by the Chairperson, the "defense" may be scheduled at a place of convenience, either in Blacksburg or off-campus. Upon completion, a Graduate School card is signed by the three committee members. Subsequently, the student may be required to incorporate any final changes in his/her document, and then acquire the signatures of the committee members on the cover sheet. The procedures for Project Reports and Theses are the same.

Section 5. Program Review and Evaluation

On an annual basis, the Systems Engineering Program will be reviewed from an academic perspective by the Academic Advisory Committee and from an administrative perspective by the ISE Department Head. The Program Chairperson is responsible to provide the necessary material for the review(s) and for the implementation of any changes that may be recommended.