FINAL REPORT

DEVELOPMENT OF AN INTERDISCIPLINARY SYSTEMS ENGINEERING PROGRAM

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GEORGIA INSTITUTE OF TECHNOLOGY

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1968-69

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1. <u>Objectives and History of the Systems Engineering Program</u>.

A study of the impact of systems engineering on engineering curricula, with a view to designing a program of study in this area, was begun at the Georgia Institute of Technology in 1961. In August 1963, Georgia Tech received a one-year grant from the National Science Foundation for the design of a typical undergraduate program of courses in systems engineering. The grant was extended for two years and ran until 1966. A further extension of the grant continued the program until November, 1968.

This study has two general objectives, namely:

(1) the definition and design of a program of courses covering those aspects of systems engineering which can be appropriately presented at the undergraduate level at most universities and (2) the practical evaluation of such a program through teaching of the courses at the Georgia Institute of Technology which is typical of a state university with strong engineering disciplinary divisions.

The following more specific objectives have also been established.

(1) The program should be at the undergraduate level.

(2) The program should provide elective courses which supplement rather than replace the more conventional disciplinary training.

(3) The courses should be interdisciplinary and emphasize the general aspects of classes of systems without domination by any one of the participating disciplines.

(4) Students from most of the engineering schools and some from the science schools would participate.

(5) A student should be able to select courses which provide a background for later advanced study.

(6) The major emphasis in all programs should be on engineering design, althought much of the underlying material will be of a mathematical analysis nature.

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(7) For an area of systems engineering to be included in the program it should: (a) constitute a body of knowledge which can be quantitatively formulated, (b) consist of knowledge which is useful in more than one of the engineering disciplines and (c) involve mathematical models which are of such a nature that they can be mastered by undergraduates.

(8) This course of study should be developed as a model program and information on it should be disseminated to other schools and interested persons.

The reasons for selecting these objectives has been outlined in previous annual reports especially the first report on this study issued May 13, 1964. A program of elective courses which seems to accomplish these objectives was formulated to the extent of naming eleven courses these courses were approved by the undergraduate curriculum committee in 1965 and were incorporated into the official undergraduate catalogue. These courses are identified by name, number, and credit hours and are listed below for reference purposes:

Course No.	Course Name	Credit Hours
Sy. E. 380	Systems Engineering I	2-3-3
Sy. E. 381	Systems Engineering II	3-0-3
Sy. E. 390	Computer Methods in Systems Engineering	2-3-3
Sy. E. 410	Systems Analysis I	4-0-4
Sy. E. 411	Systems Analysis II	4-0-4
Sy. E. 412	Systems Analysis III	4-0-4
Sy. E. 413	Systems Analysis IV	4-0-4
Sy. E. 416	Optimization of Systems	3-3-4
Sy. E. 417	Modeling and Measurement	3-0-3
Sy. E. 420	Physical Systems Laboratory	1-3-2
Sy. E. 415	Case Studies in Systems Engineering	2-6-4

Appendix A contains the descriptions and other information for the courses

in the Systems Program as listed in the official catalogue for 1968-1969

for the Georgia Institute of Technology.

II. Discussion of Progress During the Report Period (1963-1968)

The primary objective of the work during the report period has been

to design the elective courses in detail and to evaluate as many as possible

through comittee discussions and through actual teaching experience. The

general approach being employed in designing the courses as a part of

the overall program consists of development in four stages: a preliminary

design stage, two intermediate stages, and a final stage. These stages

will be referred to as stages 1 through 4 and they are defined as

follows:

Stage 1 - A course which has been designed on paper as to detailed content by a committee of several persons, usually from different disciplinary areas.

Stage 2 - A course which has been (a) taught once to an interdisciplinary class, (b) evaluated by the instructor and the Systems Engineering Committee, (c) and modified.

Stage 3 - A course which has been (a) usually taught by a second instructor (b) to an interdisciplinary class, (c) evaluated by the instructor and the Systems Engineering Faculty, (d) and modified.

Stage 4 - A course which is an intergrated part of the complete Systems Engineering Program. The notes for these courses are usually well developed.

A review of existing text material has indicated that, with a

few exceptions, appropriate texts for many of the planned courses are

not presently available. Thus, notes have been prepared for most of the

courses, and the work of preparing these notes typically extended

over all four steps in the development of each course. For the

benefit of students existing texts are being used for supplementary

reference material.

The current status of each course in the Systems Engineering Program is indicated in Table 1. As can be noted from the table, nine courses have reached stage 4: and two courses are at stage 1. All courses which have reached stage 3 or greater have been taught one or more times. Because of limited demand Sy. E 412 and 413 have not been taught to date but it is expected that these courses will be taught as the Systems Engineering Program grows and matures.

Some of the course design effort should be classified as research into system engineering theory, rather than routine course development. Systems Engineering 411 and 416 are the only courses where some text material is being used. All of the remaining courses are being developed extensively with notes. Several copies of the notes for each course reaching stage 4 are included with this report as supplementary material.

Programs of Study. As can be noted from Appendix A, two programs of study can be pursued by the student. These programs have been designated Program A and Program B. Program A consists of the following courses:

<div align="center">Program A</div>

Sy. E 380	Systems Engineering I
Sy. E 381	Systems Engineering II
Sy. E 425	Case Studies in Systems Engineering

A total of ten credit hours constitute Program A. This program is taken by the student who desires a broad coverage of systems engineering courses. Program B consists of the following courses:

<div align="center">Program B</div>

Sy. E. 380	Systems Engineering I
Sy. E. 410	Systems Analysis I
Sy. E. 411	Systems Analysis II
Sy. E. 425	Case Studies in Systems Engineering

A total of 15 credit hours constitute Program B. This course of study can be elected by the student who wishes a more mature mathematical treatment of Systems Engineering than can given by Program A.

Table 1: Stages of Development of Systems Engineering course

Course	Stage of Development (As of Nov., 1968)	Stage of Notes			Times Taught as of Nov., 1968	Remarks
		Rough draft	Intermediate draft	Final draft		
Sy.E. 380 Systems Engineering I: 2-3-3	4			X	12	See supplementary notes for detailed course content
Sy.E. 381 Systems Engineering II: 3-0-3	4			X	5	See supplementary notes for detailed course content
Sy.E. 390 Computer Methods in Sy.E. 2-3-3	4			X	2	See supplementary notes for detailed course content
Sy.E. 410 Systems Analysis I: 4-0-4	4			X	4	See supplementary notes for detailed course content
Sy.E. 411 System Analysis II: 4-0-4	4			X	4	See supplementary notes for detailed course content
Sy.E. 412 System AnalysisIII: 4-0-4	1				–	OUTLINE ONLY
Sy.E. 413 System Analysis IV: 4-0-4	1				–	OUTLINE ONLY
Sy.E. 416 Optimization of Systems. 3-0-3	4			X	–	See supplementary notes for details of course content
Sy.E. 417 Modeling and Measurement. 3-0-3	4			X	1	See supplementary notes for details of course content
Sy.E. 420 Physical Systems Laboratory 1-3-2	4			X	1	See supplementary notes for details of course content
Sy.E. 425 Case Studies in Systems Engineering. 2-6-4	4			X	2	See supplementary notes for details of course content

Development of the Systems Engineering Program at the Georgia

Institute of Technology: Since the inception of the Systems Engineering

Program at the Georgia Institute of Technology in 1963 many difficulties

with the committee method of dealing with problems peculier to the program

became apparent. These problems ranged from the development of student

interest in the program to the obtaining of faculty to teach the courses

and to perform committee work. Consequently, in March, 1967, the structure

of development and administration on the Systems Engineering Program

was changed. Basically the changes that were submitted to A. G. Hansen,

Dean of Engineering, were as follows:

1. The Systems Engineering Program would operate as a depart-
    ment within the School of Industrial Engineering.

2. Two faculties, each with responsibilities and prerogatives
    dealing with their own areas of (a) Industrial Engineering
    and (b) Systems Engineering would be appointed.

3. The Systems Engineering Faculty would be new, and will be
    composed of full and part-time members selected by the Sys-
    tems Engineering Committee for initial organization from:
    (a) the System Engineering Faculty (b) from interested
    Industrial engineering faculty and (c) recruited from other
    sources.

4. A member of the Systems Engineering Faculty will be appointed
    as Chairman of the Systems Engineering Programs. This person
    will serve as administrative officer for the program and will
    be responsible to the Director of the School of Industrial
    Engineering.

5. An Advisory Committee to provide general guidance to the
    Systems Engineering Faculty and Director of the School of
    Industrial Engineering shall be appointed. The objectives
    of such an arrangement are to help insure a cross-disciplinary
    flavor within the Systems Engineering Program and to encourage
    the cross-campus interchange of attitudes and to facilitate
    responsiveness of the Systems Engineering Faculty to the
    needs and desires of other academic units. Advisory committee
    membership will be open to meet representatives from each
    interested Engineering School and academic department on the
    Campus. The committee will meet for the purpose of review of the
    Systems Engineering activity and to recommend ways in which
    better cross-disciplinary endeavors can be encouraged and fa-
    cilitated.

6. The School of Industrial Engineering plans to change its designated name to the Schools of Industrial Engineering and Systems Engineering or alternatively to the School of Industrial and Systems Engineering.

The Systems Engineering Program has started to operate with the changes which are proposed above. A more vibrant and effective program which can better meet the needs of students and attract qualified faculty is developing with these changes.

III. Current Status and Planned Directions of Course Development:

The current stage of development of each course is given in Table 1. The purpose of this section is to summarize the detailed content of each course, to discuss its role in the overall program and to indicate specific directions of future work. This summary will be made for each course under four headings: (1) Objective of course and its relation to the overall program (2) Topical outline (3) Considerations in evaluation of course content and (4) Future plans.

SY.E 380 Systems Engineering I, 2-3-3:

Objective and Relation to Overall Program: Sy.E 380 is intended to introduce the student to systems engineering as a professional area and also to introduce him to some of the theoretical activities of systems engineering upon which other courses will develop in much greater detail. The course presents qualitative and quantitative concepts of systems engineering and can be taken by the student as early as the third quarter of the Sophomore year and has differential equations as a mathematics corequisite.

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Topical Outline

No. of Periods	Topic
2	General System Theory and System Science
1	Systems Science and Related Disciplines
3	The Nature of Man-Machine Systems
3	Biotechnology and Human Engineering
3	To Systems Design
3	The Nature of Models
3	Economic Aspects of Systems Evaluatioı
2	Const. Considerations in Systems Analysis and Design
3	Decision Making in Systems Engineering
2	in Systems Design
2	Some Advanced Optimization Techniques
3	Computer Simulation Techniques

30 Total

TEXT

Introduction to Design by Morris Asimow.

A set of notes which were compiled by Dr. Joseph Krol are also being used for this course.

Considerations in Evaluation of Course Content: Some minor changes

are still being made in this course which reflects the evaluation of

thinking as to its proper content to meet the requirements of Program A.

Future Plans: The content of this course will vary somewhat as

changes are made in its content to reflect changes which occur in other

courses, especially Sy.E. 380. Some consideration is also being given

to the inclusion of this course as a requirement in Program B.

Sy.E. 390 COMPUTER METHODS IN SYSTEMS ENGINEERING, 2-3-3:

Objectives of Course and Relation to Overall Program: This course

provides the student with a rudimentary background in analog and digital

computer methods. The student will have sufficient knowledge of the

computer after completion of this course to enable him to program analog

and digital computers for problem solving involved in Sy. E. 425.

Topical Outline:

No. of Periods	Topic
2	Introduction to Analog and Digital Computation
4	Analog and Digital Notation
5	Illustrative Programs, Flow Diagrams
1	Analog, Simulation of Transfer Function
8	Digital Computers-Basic Language and Problem Solving
10	Analog Computer-Summing, Intergration, Multiply, Dividing, and Problem Solving
Total 30	

Consideration in Evaluating of Course Content: There is considerable pressure

to reduce the number of courses in the systems engineering sequence. Since

basic computer technology is taught in several schools of the campus,

and especially in the School of Information Science, this course

cannot produce a unique service to the university.

Future Plans: This course as presently structured, was taught in the winter quarter, 1968 for the last time. This course will be reconstructed so that it becomes an advanced computer science course and other computer courses, particularly Information Science 151, will be used as a prerequisite. SY.E. 410, 411, 412, and 413, SYSTEMS ANALYSIS I,II,III, AND IV, 4-0-4: Objective of Courses and Relation to Overall Programs: These systems analysis courses are intended to present those mathematical tools of system engineering analysis which can be mastered at the undergraduate level. Sy.E. 410 presents mathematical tools for the analysis of linear deterministic systems with and without memory. Sy.E. 411 discusses the analysis of linear non-deterministic systems without memory. Sy.E. 412 will discuss tools for the analysis of linear non-deterministic systems with memory and Sy. E. 413 will be concerned with special techniques for deterministic systems. Also included in Sy. E. 413 will be a study of techniques for the analysis of nonlinear and distributed parameter systems.

Sy.E. 412 and Sy. E. 413 have not yet been planned in detail. Outlines for Sy. E. 410, Sy. E. 411, Sy. E. 412, Sy. E. 413 are given below. Sy.E. 380 will be a prerequisite for Sy. E. 410 and each of the systems analysis courses will be a prerequisite for the next higher number.

Topical Outline for Sy. E 410:

No. of Periods	Topic
2	Review of Sy. E 380
9	Matrix Algebra and Solution of Equations describing Linear Systems
10	Variation of Parameters and Laplace Transforms Techniques for Solution of Differential Equations
8	Matrix Solution in the Laplace and Time Domain
2	System Response to Step, Impulse, and Sine Waves
9	Concepts in Feedback Systems

40 Total

Topical Outline for Sy. E 411

No. of Periods	Topic
3	Introduction to Probability
3	One Demensional Random Variables
3	Functions of One Random Variable and Expectation
3	Higher-Demensional Random Variables
3	Important Discrete Distributions
3	Important Continous Random Variables
4	The Normal Distribution
3	Markov Processes
9	Queuing Models
3	Simulations
3	Reliability Models

40 Total

Topical Outline for Sy. E. 412 (Tentative)

No. of Periods	Topic
6	Introduction Types of Computers
9	Topics From Linear Algebra
9	Finite Difference Approximating
9	Numerical Matrix Operations
7	Numerical Solutions to Ordinary Differential Equations

40 Total

Topical Outline for Sy. E. 413 (Tentative)

No. of Periods	Topic
6	Review of Probability
9	Basic Notions of Stockastic Processes
7	Density and Power
9	Markov Processes
9	Random Processes in Linear Systems

40 Total

Consideration in Evaluation of Course Content: As indicated in Table 1

Sy.E. 410 and Sy. E. 411 have been given several times. Because

of substantial similarities Sy. E. 411 has been cross-listed with a course

in the School of Industrial Engineering entitled, I.E. 335. Sy.E. 410

and Sy.E. 411 have undergone substantial revisions since their

original teaching. The initial courses were centered around the

teaching of the mathematics required to analyse various linear systems.

Later versions of these courses concentrated on the systems engineering

problems and the mathematical formulation of the problem was studied

as an outgrowth of the stated engineering problem. Mathematics are used as

a tool for the analysis of the systems problem and were appropriate

computational methods are taught as a means to solve the systems engineering

problem.

To implement the approach to teaching just discussed, a program of

study into system types and their common mathematical models was

begun. This study has shown that a useful system classification can be made

on the basis of the following system properties: (1) The system

variable i.e., input-output stages and time, (2) The type of space on which

the variables are defined and (3) The type of input-output or state-output

transformation. As a consequence, a system can be classified on

the basis of a number of specific properties derived from these three

catagories. For example, the input-output variables of the system can be

stochastic of deterministic, the spaces can be trivial, discrete, or

continious and the transformation can be linear, nonlinear, time

invariant or time variable. Every class of system required a potentially

different type of mathematical model.

The major distinctions in mathematical models seem to be

associated with the type of input-output variables, i.e., whether deterministic

or stochastic, and with the transformation in so far as it does or does

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not have memory. These four categories have been used to obtain the division of material between the four analysis courses which has been stated previously.

Plans call for this classification being made in the analysis courses to be followed throughout the elective program. This approach seems to have the following advantages. (1) Duplication of effort will be avoided because most theories and techniques apply to a particular class of systems. (2) The simularities of systems within classes and dissimilarities between systems of different classes will be displayed. (3) General equations describing systems in a given class can be developed to provide a standard description of various systems. (4) Identification of a system can be aided by placing it in a specified class. (5) The classification will aid in presenting a theory of systems so that the properties of all systems in given classes can be developed.

Future Plans: Plans call for a continued effort in refining the classifications discussed above. A concentrated effort will be made to develop nore illustrative examples and to introduce each mathematical techniques as a tool for analysis of a given class of systems. Because of lack of student demand, Sy.E. 412 and 413 have not been taught to date. However, it is expected that these courses will be taught as the Systems Engineering Program develops.

SY.E. 416 - OPTIMIZATION OF SYSTEMS, 3-3-4:

Objective of Course and Relation to Overall Program: Optimization techniques are sufficiently important in systems engineering to concentrate them in a separate course in the program. Because of the great similarities in this course and a course, I.E. 334, entitled "Optimization Methods, " which is presently taught in the School of Industrial Engineering, I.E. 334, will be taken by students who desire credit for Sy.E. 416. Four credit hours will be given for this course.

instead of three credit hours as initially envisioned for this course. This change was made because I.E. 334 is a four credit-hour course.

Topical Outline:

No. of Periods	Topic
7	Methods of Classical Calulus for Optimization
3	Finite Differences
20	Use of Linear Programming for System Optimization
4	Special Forms of Linear Programming
3	New Work Problems
3	Dynamic Programming
Total 40	

Text: Introduction to Management Science by Daniel Teichroew, published by John Wiley and Sons, Inc. and course notes developed by Professor Stanley Aaronson.

Consideration in Evaluation of Course Content: Because of large similarities, Sy.E. 416 has been cross listed with the course, I.E. 334, "Optimization Methods". Because of this substantial similarity, little change is contemplated in I.E. 334 to accomodate students in systems engineering.

SY.E. 417 MODELING AND MEASUREMENT 3-0-3:

Objective of course and Relation to Overall Program: Sy.E. 417 is concerned with the problem of determining a mathematical model for a system or a system component through the use of observed or measured data. General characteristics of measurement instruments are developed and incorporated in the techniques of the formulation of models. A course such as this is required to a planned system program to provide information about physical systems and mathematical models which represent them.

The measurement instruments studied in this course, are in general, deterministic systems with memory and with potentially stochastic inputs.

The major emphasis in modeling is on linear time invarient deterministic systems. Sy.E. 410 and Sy.E. 411 are required prerequisities for this course.

Topical Outline:

No. of Period	Topic
1	Introduction
3	General Structures of Measurement Instruments
3	Mathematical Description of Physical System
5	Noiseless Linear Measurement Instruments
	a. Read-Out Component
	b. Estimation System
4	Model Identification from Noise-Free measurements
	a. Excitation from Identification
	b. Identification Methods
4	Mathematical Models for Measurement System Errors
4	Measurement System Error
4	Noisy Measurement Instruments
2	Illustrative Practical Measurement Systems

30 Total

Consideration in Evaluation of Course Content: Because of the lack of students who have taken Sy.E. 410 and Sy. E. 411, this course is presently being offered without all of the required prerequisites. Consequently, approximately nine periods are presently used in this course to review mathematical tools for the analysis of deterministic and non-deterministic systems. It is anticipated that the prerequisite problem will be overcome when the program is more fully developed and matured.

Future Plans: The prerequisite problems discussed above will be overcome as the program is more firmly established.

SY.E. 420 PHYSICAL SYSTEMS LABORATORY, 1-3-2

Objective of Course and Relation to Overall Program: The physical systems laboratory is intended to provide some contact with actual physical systems and system components. Emphasis in this laboratory will be on mechanical

and electromechanical devices.

Sy E. 420 is planned for the senior year . This course has been taught
one time to date and is essentially complete including the preparation of
laboratory notes.

EXPERIMENT NUMBER 1— MECHANICAL   VIBRATION

This experiment is concerned with demonstrating mechanical
virbrations, and also with illustrating the use of frequence response
techniques to determine mathematical models for relatively complex systems.
A torsional vibrating system is part of the equipment available for this experiment.

EXPERIMENT NUMBER 2 – ROTATING COMPONENTS

This experiment consists of transient and sinusoidal type tests
of an interconnected group of rational mechanical components including
a servo motor and gears connected in both an open and closed loop
configuration. Electrical, hydraulic and mechanical components are also
available for use in this experiment.

EXPERIMENT NUMBER 3– PROCESS CONTROL

The lab is equipped with a large water tank and controllers for both
water level and water temperature.   A simple on-off controller is used
for water level and a three mode controller for temperature. This experiment
demonstrates fluid and thermal systems and allows the student to
become acquainted with the types of controllers used in the process industry.

EXPERIMENT NUMBER 4– STATISTICAL PARAMETERS

This experiment illustrates some of the principles of statistics and
reliability. A Graeco–Latin model is used to determine the

statistically significant parameters that influence the outcome of an experiment, in this case the failure of a number of overloaded light bulbs. Additional equipment to measure the mean time to failure is also provided.

EXPERIMENT NUMBER 5- HUMAN FACTORS

This experiment is concerned with the problem of determining a mathematical model for a human operator performing a simple function. The experiment involves equipment consisting of two projectors and a screen. One of these projectors is programmed to give a predetermined motion to a projected image on a fixed screen. The other projector is manually operated and the operator is given the task of matching the programmed motion. After performing an experiment, a mathematical model is determined from the two recorded motions.

Considerations in Evalution of Course Content: The considerations which have determined the experiments listed are the following: (1) The laboratory should expose the student to a variety of different types of physical devices and systems, (2) The lab should enable the student to gain experience in the use of modern laboratory measuring and recording equipment, and (3) The laboratory should provide the opportunity to apply some of the techniques learned in the previous systems courses.

Future Plans: The physical assembly of the laboratory is complete. Future offerings of this course will provide the student with well documented information and the experience of working with physical systems.

SY. E 425 CASE STUDIES IN SYSTEMS ENGINEERING, 2-6-4.

Objective of Course and Relation to Overall Program:Any complete elective program in systems engineering should contain some experience in actual

systems design. Some design problems can be included in courses such as Sy.E. 380 or the Systems Analysis sequence, but such problems must necessarily be of such limited scope. Each planned sequence of elective courses contains Sy.E. 425 to give each student the experience of making studies of all the aspects of a complete system.

As discussed elsewhere in this report, it has been necessary to offer students a great deal of flexibility in the amount of work in their elective programs. The Case Studies Course along with Sy.E. 380 and Sy.E. 381 has been chosen as an essential part of the minimum program A, and thus Sy.E. 380 and Sy.E. 381 as well as Sy.E. 390 followed by work in the systems analysis sequence are accepted as prerequisite material.

Presently this course has been taught two times, the first time during Spring Quarter of 1965 and for the second time during the Spring Quarter of 1966. A solution of a single large scale system was attempted during each offering. Although the students became involved in the solution of these large single system problems their experience was limited because time permitted them to work only on one project. Team effort was needed and emphasized in the solution of these problems.

Topical Outline

No. of Periods	Topic Introduction
20	Work on a Systems Design Problem
20	Lectures on Important Topics in Systems Engineering (Decision making processes)

40 total

Considerations in Evalution of Course Content: The project chosen for the system design problems should contain sufficient elements to give the student broad experiences in the design of a large scale system. Large complex systems should not be considered for this course unless the study is permitted to make simplifying assumptions. This type of problem should

also be discouraged because it tends to make the design problem unrealistic.

A large scale system design was initially attempted. During the Spring Quarter of 1967 the Sy. E 425 class joined a class of graduate students who had already worked one quarter on the design of a mass transportation system for the City of Atlanta.* This system was to be made capable of moving persons within the central business district of Atlanta after persons had disembarked from mass transit facilities which fed the city centers. The System Committee felt that this type of problem and its prior development led to a successful conclusion.

This course was taught by teachers and outside experts on a team basis so that the expertise of various disciplines could be used to help solve the complex system problem.

Future Plans: Future plans for the development of this course are concerned with the introduction of the Case Method of teaching. It is felt by the Systems Faculty that this teaching technique could prove to be quite valuable in this course. The Case Method of teaching has the ability to make the student think his way through a complex system design by considering the successes and failures of system design as illustrated by the Case Method. The Case Method will be employed when this course will be taught in the future.

IV. Conclusions from the Study to Date: Conclusions relative to the first general objective of the program: namely, that of determining the technical content of an elective program in systems engineering, are contained in the discussions of course content above and is summarized in Table 1. The purpose of this section is to discuss what has been learned so far with respect to the second general objective of evaluating

* See Downtown Atlanta Rapid Transit. A Graduate Project in Complex Systems Design. Completed by the students from the Georgia Institute of Technology, June 1967

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the implementation of the elective program at a state university with strong disciplinary divisions.

The number of elective hours available to students in the different disciplinary schools at Georgia Tech varies from a minimum of 10 to a maximum of 33 quarter hours. Furthermore, each individual school presently holds tight control over most of these elective hours. Thus it is becomming more and more obvious that a change in the elective policies of the entire engineering college will be necessary to attract many students into a major fraction of the planned elective courses. The change would have to make it possible for students to substitute systems courses for what are now considered required disciplinary courses.

The Systems Engineering Program has already been adopted as an elective option within the School of Industrial Engineering and to some extent in the School of Electrical Engineering.

Thus rather than restrict the program to a fixed number of elective courses, the systems engineering faculty decided to offer the students a flexible curriculum with two major choices as to elective content. The elective programs resulted in the development of Program A and B and are shown in the appendix. In keeping with the fact that students are finding it difficult to free many hours for systems electives, the systems faculty made a critical examination of the planned courses with a view to eliminating those which are not exclusively systems oriented. This examination focused attention on Sy.E. 390, in the elective program. In addition course cross listings were considered. The study resulted in the cross listing of Sy. E. 416 with the already existing course, I.E. 334, Optimization Methods and the cross listing of Sy. E. 411 with the course, I.E. 335, "Applications to Probability"

The material contained in Sy. E. 390 is available in two other existing courses in the engineering college, Sy. E. 390 has been offered two times with a moderate degree of success. Future plans include extending the material in this course to build upon information obtained in more elementary computer courses offered on the Georgia Tech campus.

V. <u>Other Activities of the Systems Engineering Committee:</u> In addition to course development studies, the members of the Systems Engineering Committee also engaged in other types of activity which contributed to their professional competance and enable them to exchange ideas with persons from other universities and industry. In the past five years members of the Systems Engineering Faculty have attended and participated in numerous seminars and discussions which directly related to the systems engineering study at Georgia Tech. Members of the committee have also presented several papers dealing with the present study and other related topics to the subject of systems engineering.

VI. <u>The Symposium on Systems Engineering:</u> A Symposium was held on the Georgia Tech campus on October 23 - 24, 1968.
The Symposium was concerned with a discussion of the following topics:

    (a) Systems Engineering Program at Georgia Tech

    (b) Systems Engineering Programs at Other Universities

    (c) Systems Engineering and Systems Theory

    (d) Role of Industry in Systems Engineering Education

    (e) Systems Engineering and Design

The topics were discussed by leading authorities in various topics in systems engineering. A list of the speakers is as follows:

Speakers:

Dr. Harold Chestnut, Manager
Systems Engineering & Analysis Branch
General Electric Company
Schenectady, New York

Dr. Donald O. Covault
Professor of Civil Engineering
Georgia Institute of Technology
Atlanta, Georgia

Professor Arthur D. Hall, III
Moore School of Electrical Engineering
University of Pennsylvania
Philadelphia

Dr. Arthur G. Hansen
Dean of Engineering
Georgia Institute of Technology
Atlanta, Georgia

Dr. Robert N. Lehrer, Director
School of Industrial Engineering
Georgia Institute of Technology
Atlanta, Georgia

Dr. Mihajlo Mesarovic
Head, Systems Engineering Division
Case Western Reserve University
Cleveland, Ohio

Dr. Allen B. Rosenstein
Department of Engineering
University of California
Los Angeles, California

Dr. A. Wayne Wymore
Department of Systems Engineering
University of Arizona
Tucson, Arizona

Professor Pranas Zunde
Chairman, Systems Engineering Program
Georgia Institute of Technology
Atlanta, Georgia

A copy of the Symposium program and persons attending the Symposium
is shown in the Appendix B. Including the speakers and presiding
officers, a total of 63 persons attended the Symposium. Eighteen of
the participants were from various universities in the United
States and the remaining represented various industries. These
participants help to produce a very informative and stimulating program.

VIII. <u>Plans for the Future</u>: The purpose of this section is to sumarize
plans for the overall program. Reference to Table 1 gives the status
of the courses in the Systems Engineering Program. As indicated by this
table, all courses will have reached stage 4 in development with the
exception of Sy. E. 412 and Sy. E. 413. It is estimated that when
student demand develops these courses will be developed to stage 4.

On November 30, 1968, the grant from the National Science
Foundation for the development of the Systems Engineering Program at
Georgia Tech terminated.Georgia Tech will continue the program developed
under the grant. Plans are now underway to develop the Systems
Engineering Program as a formalized course of study with possible degree
granting status. Various plans are also being developed with the
School of Information Science in the offering of a graduate program in System
Science. Tentative programs have also been suggested for a course of
study in System Analysis. All of these proposals have been very tentative
and the future development of the various ramifications of the present
Systems Engineering Program to degree granting status is to some
extent uncertain.

Placement of the Systems Engineering Program in the School of
Industrial Engineering administrative structure has strengthened the
program and has promoted a more secure basis of operation. This
organization is expected to continue until the time the System
Engineering Program reaches degree granting status and becomes a

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department or school on the Georgia Tech campus.

The appointment of an interdisciplinary faculty will be encouraged and continued. In addition faculty will be acquired which will spend full time on systems engineering.

Dr. Pranas Zunde has been appointed Chairman of the Systems Engineering program. He replaces Dr. Donald O. Covault who was Acting Chairman of the Program.

Appendix A

Catalog Description of the Systems Engineering

Program at The Georgia Institute of Technology

1968-1969

Systems Engineering Program

(Established in 1965)

The Systems Engineering program is administered by the School of
Industrial Engineering, in conjunction with a campus-wide Committee
which advises on the interrelationship between systems engineering and
other engineering programs. It is an interdisciplinary activity
dealing with systems implications of engineering, and may be elected
as a planned option to supplement and complement curricula in any of
the engineering schools. Dr. Pranas Zunde, Associate Professor of
Systems Engineering and Information Science, serves as Chairman, Systems
Engineering, and is available for consultation and advising students
in planning Systems Engineering course work. A designated major in
Systems Engineering is currently being planned.

What is Systems Engineering?

Systems engineering emphasizes the coordination of man and machines
in complex arrangements. It is largely a development of the last 25
years and has received impetus from the building of defense systems
and the rapid development of other forms of modern technology.
Computers and automated equipment play a role in virtually all systems
engineering efforts.

The concepts of systems engineering are as important today for civil
engineers designing complicated highway systems as they are for
electrical engineers devising sophisticated communication systems.
Teams of engineers and scientists use systems engineering principles
to build the systems that make possible flights of missiles, to
develop transportation systems and many other complex jobs.

Planned Systems Engineering Programs

Two elective programs in systems engineering are offered. Program
A consists of 10 quarter credit hours of course work. This program has
been tailored for students who have a limited number of elective hours
and who wish to obtain a basic knowledge of systems engineering.
Program B involves a minimum of 15 quarter credit hours of course work
and has been tailored for students who want to study more about the
mathematical bases of systems engineering and who would like to go
on to more advanced work in the field. An additional 20 quarter credit
hours of advanced work is also available as part of this program.

Case Studies in Systems Engineering (Sy.E. 425) is contained in
both Program A and B. This course gives the student an opportunity
to design a system as a member of a design team, and illustrates the
important team approach required in the solution of systems engineering
problems.

PROGRAM A

Course				Credit Hours
Sy.E.	380	Systems Engineering I	....	2-3-3
Sy.E.	381	Systems Engineering II	....	3-0-3
Sy.E.	425	Case Studies in Systems Engineering	....	2-6-4
		Total	....	7-9-10

PROGRAM B

Course				Credit Hours
Sy.E.	380	Systems Engineering I	....	2-3-3
Sy.E.	410	Systems Analysis I	....	4-0-4
Sy.E.	411	Systems Analysis II	....	4-0-4
Sy.E.	425	Case Studies in Systems Engineering	....	2-6-4
		Total	....	12-9-15

ADDITIONAL COURSES

Course				Credit Hours
Sy.E.	390	Computer Methods in Systems Engineering	......	2-3-3
Sy.E.	412	Systems Analysis III	....	4-0-4
Sy.E.	413	Systems Analysis IV	....	3-3-4
Sy.E.	416	Optimization Methods	....	3-3-4
Sy.E.	417	Modeling and Measurement	....	3-0-3
Sy.E.	420	Physical Systems Laboratory	....	1-3-2
		Total	....	17-9-20

Courses of Instruction

Note: 2-3-3 means 2 hours class, 3 hours laboratory, 3 hours credit.

Sy.E. 380. Systems Engineering I
2-3-3. Prerequisite: Math. 304, or concurrent.
     As an introduction to the theory of systems engineering, this course is designed to acquaint the student with the scope of activities and the fundamental concepts and definitions involved in systems engineering. Basic theoretic notions necessary for analytical treatment of engineering systems are presented. The concepts of systems, sub-systems, and components are defined; and illustrative systems, both deterministic and non-deterministic, from several fields are presented and analyzed.

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Sy.E. 381. Systems Engineering II
3-0-3. Prerequisite: Sy.E. 380
   A continuation of Sy.E. 380.
Topics in engineering economy, deci-
sion, theory, optimization of systems,
system reliability evaluations, and
network planning will be discussed.
The construction of state equations
for systems will be emphasized.

Sy.E. 390. Computer Methods in
   Systems Engineering
2-3-3. Prerequisite: Math 304
   An introduction to the operational
characteristics of analog and digital
computers will be presented. Funda-
mental machine operations are dis-
cussed and related to the numerical s
solution of equations. Emphasis is
placed on problem formulation. Ele-
mentary principles of machine pro-
gramming will be given.

Sy.E. 410, 411, 412, 413. Systems
   Analysis I, II, III, IV
4-0-4. Prerequisite: Sy.E. 380 or con-
sent of instructor.
   This sequence of courses presents
a unified treatment of analytical
techniques for the analysis, design,
and reliability evaluation of systems.
Mathematical models will be devel-
oped which describe the characteris-
tics of classes of linear and non-linear
deterministic and non-deterministic
systems. Analytical and
numerical techniques for treatment of
these models will be presented.
Application will be made of such
topics as linear algebra, operational
mathematics, probability, statistics,
and approximation methods. Input-
output analysis, response and stability
characteristics of systems will be
stressed. (Sy.E. 411 is cross-
listed with I.E. 335 Applications
of Probability.)

Sy.E. 416 Optimization Methods
3-3-4. Prerequisite: Sy.E. 411
   Techniques for system and sub-
system optimization are presented
with emphasis on methods yielding
practical numerical procedures.

Specific topics include: linear and
dynamic programming, steepest as-
cent or descent procedures, proced-
ures using the calculus of variations,
miscellaneous search techniques.
(Sy.E. 416 is cross-listed with I.E.
334 Optimization Methods.)

Sy.E. 417. Modeling and Measurement
3-0-3. Prerequisite: Sy.E. 411.
   Construction of mathematical mod-
els for systems using measured data
will be discussed. The characteristics
and use of physical measuring in-
struments and the statistical theory
of measurements will be presented
in a unified manner. The effect on
the models of measuring instruments
and errors in measurement will be
studied.

Sy.E. 420. Physical Systems Laboratory
1-3-2. Prerequisite: Sy.E. 417.
   This is a laboratory course de-
signed to give the student experience
with systems composed of components
from several fields. The work will
include experiments with mechanical,
electrical, hydraulic, chemical, pneu-
matic, and human elements. The experi-
ments will be designed to illustrate
important concepts of systems engineer-
ing covered in prerequisiste courses.

Sy.E. 425. Case Studies in Systems
   Engineering
2-6-4. Prerequisite: Sy.E. 381 and
Sy.E. 390 or equivalent and senior
standing.
   Selected engineering problems are
to be solved using systems procedures
and concepts. A multidisciplinary
team will be assigned to each problem.
Specific knowledge in component design
and analysis techniques is required.
The laboratory periods will be used
for the design of a system and the
lecture periods will be used to present
specific systems engineering topics.

Appendix B

PROGRAM AND PARTICIPANTS

FOR THE SYMPOSIUM ON SYSTEMS

ENGINEERING

October 24-25, 1968

Held on the Campus of the

GEORGIA INSTITUTE OF TECHNOLOGY

Atlanta, Georgia

<p style="text-align: center;"><u>Friday</u>, <u>October</u> <u>25</u>, <u>1968</u></p>

<p style="text-align: center;">Presiding: Herman E. Koenig</p>

9:00   Problems of Defining a Systems Program at a Technological Institute

Arthur G. Hansen

10:15 Coffee Break

10:30 The Role of Systems Theory and Systems Engineering in Systems

Design - Allen B. Rosenstein

12:00 Lunch

<p style="text-align: center;">Presiding: Lotfi A. Zadeh</p>

1:30   The Role of Industry in Systems Engineering - Harold Chestnut

3:15   Coffee Break

3:30   Systems Engineering Concept - Its Extensions and Intentions

Arthur D. Hall, III

4:30   Adjourn

PROGRAM FOR SYSTEMS ENGINEERING SYMPOSIUM

GEORGIA INSTITUTE OF TECHNOLOGY

Thursday, October 24, 1968

Presiding: Robert N. Lehrer

8:30 Registration

9:10 Welcome Address: Edwin Harrison

9:15 Remarks: Robert N. Lehrer

9:30 Systems Engineering Program at the Georgia Institute of Technology

Donald Covault

10:30 Coffee Break

Comments:

Joseph Hammond	Sy. E. 380
Joseph Krol	Sy. E. 381
Thomas White	Sy. E. 390
Stephen Dickerson	Sy. E. 410
William Hines	Sy. E. 411
Stanley Aaronson	Sy. E. 416
Joseph Hammond	Sy. E. 417
Eugene Harrison	Sy. E. 420
Donald Covault	Sy. E. 425

Discussion

12:00 Lunch

Presiding: Richard F. Vidale

1:30 Survey of Systems Engineering Programs - Pranas Zunde

2:30 Model Curriculum in System Engineering and System Theory - A. Wayne Wymore

3:30 System Theory as an Academic Discipline - Mihajlo Mesarovic

5:00 Adjourn

7:30 Workshop on Systems Engineering

ATTENDANCE

SYSTEMS ENGINEERING SYMPOSIUM

October 24-25, 1968

GEORGIA INSTITUTE OF TECHNOLOGY

Atlanta, Georgia

1. Stanley Aaronson
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15. Margaret E. Dexter
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16. Stephen Dickerson
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25. Arthur Hansen
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    Georgia Institute of Technology
    Atlanta, Georgia

26. Edwin Harrison, President
    Georgia Institute of Technology
    Atlanta, Georgia

27. Eugene Harrison
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