THE USE OF COMPUTERS IN ENGINEERING EDUCATION

Final Report of Project
Supported by The Ford Foundation

College of Engineering
The University of Michigan
Ann Arbor

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THE USE OF COMPUTERS IN MECHANICAL ENGINEERING EDUCATION
THE USE OF COMPUTERS IN ELECTRICAL ENGINEERING EDUCATION
THE USE OF COMPUTERS IN MATERIALS AND METALLURGICAL ENGINEERING EDUCATION
THE USE OF COMPUTERS IN INDUSTRIAL ENGINEERING EDUCATION
THE USE OF COMPUTERS IN ENGINEERING MECHANICS EDUCATION
THE USE OF COMPUTERS IN NAVAL ARCHITECTURE EDUCATION
THE USE OF COMPUTERS IN CIVIL ENGINEERING EDUCATION
THE USE OF COMPUTERS IN AERONAUTICAL ENGINEERING EDUCATION
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ELECTRONIC COMPUTERS IN ENGINEERING EDUCATION
USE OF COMPUTERS IN ENGINEERING EDUCATION
SECOND ANNUAL REPORT
Project supported by
FINAL REPORT
THE USE OF COMPUTERS IN ENGINEERING EDUCATION
College of Engineering
The University of Michigan
Ann Arbor
AN INTRODUCTION TO DIGITAL COMPUTING
BRUCE W. ARDEN
ANALOG COMPUTER FUNDAMENTALS
With an Introduction to Matrix Programming Methods
by
Silvio O. Navarro
The Language of Computers: An Introduction
BERNARD A. GALLER
Assistant Professor of Mathematics and
Research Associate, Computing Center
THE USE OF LOGIC IN SOLVING ENGINEERING PROBLEMS
Report of Study on Computer Project
Supported by The Ford Foundation in
The University of Michigan,
College of Engineering
A COMPUTER PRIMER
FOR THE
MAD LANGUAGE
Elliott I. Organick

LITERATURE PUBLISHED AND DISTRIBUTED BY THE PROJECT

MAJOR PROJECT REPORTS:

1. First Annual Report, Project on the Use of Computers in Engineering Education, August 26, 1960.
2. Second Annual Report, Project on the Use of Computers in Engineering Education, December 15, 1961.
3. Final Report, Project on the Use of Computers in Engineering Education, January 1, 1963.

PRINCIPAL TEACHING TEXTS:

4. A Computer Primer for the MAD Language, Organick, E. I., 1961.
5. The Language of Computers, Galler, B. A., 1962.
6. An Introduction to Digital Computing, Arden, B. W., 1962.
7. Analog Computer Fundamentals, Navarro, S. O., 1962.
8. The Use of Logic in Solving Engineering Problems, Carnahan, B., Copi, I. M., Katz, D. L., Navarro, S. O., Squires, R. G., and F. H. Westervelt, 1962.

CURRICULUM STUDIES: USE OF COMPUTERS IN

9. Aeronautical Engineering Education, Isakson, G. and R. M. Howe
10. Chemical Engineering Education, Briggs, D. E., B. Carnahan, G. B. Williams
11. Civil Engineering Education, Welch, H. J.
12. Electrical Engineering Education, Scott, N. R.
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15. Mechanical Engineering Education, Westervelt, F. H.
16. Materials and Metallurgical Engineering Education, Sinnott, M. J. and L. H. Van Vlack
17. Naval Architecture Education, Yagle, R. A.

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18. First Progress Report, Project on Use of Computers in Engineering Education, 1960.
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22. "Conference Report on the Use of Computers in Engineering Classroom Instruction," 1960.
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28. A Modern History of Machine Organization, Rosin, R. F., 1962.
29. An Introduction to the Theory and Application of Analog Computers, Howe, R. M., 1960.
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FOREWARD

In 1959 it was observed that experiences with computers in research were filtering down very slowly into undergraduate engineering education. To accelerate this process and to study the feasibility of broad scale integration of electronic computer use into the educational process, a demonstration project under Ford Foundation sponsorship was organized at The University of Michigan.

Initial Project objectives were the development of appropriate teaching material and the training of faculty and students in computer use. Once the faculty and student body had attained adequate proficiency, computers could be used as problem solving tools in required upper-level engineering problem courses.

This report covers the activities of the Project on the Use of Computers in Engineering Education from October, 1959, through November, 1962.

ABSTRACT

During the past three years the faculty of the College of Engineering of The University of Michigan has been exploring the use of digital and analog computers in the undergraduate curricula. Extensive computer activity by faculty and students has been in large measure initiated, encouraged, and supported by the Project on the Use of Computers in Engineering Education sponsored by The Ford Foundation.

Major objectives of this Project were: (1) the training of the engineering faculty, (2) the development of introductory computer courses for undergraduate engineering students, (3) the publication of useful teaching literature, and (4) the generation of a large body of completely solved computer-oriented engineering problems suitable for classroom use. Important early policy decisions were to document Project activities as thoroughly as possible and to give wide distribution of Project publications to engineering college faculty members and administrators throughout the United States and Canada.

This Final Report of the Project describes in detail the following:

Faculty Training Programs: Fifty-six University of Michigan faculty and 160 faculty members from 65 other engineering schools have participated in various Project training programs.

Introductory Computer Courses: Two courses for undergraduate engineering students are now being taught at the University. Results of a Project survey indicate the nature of introductory computer courses at engineering schools throughout the country.

Computing Center Services: Detailed statistics show the extent of current computing activity at the University and indicate the kind of services provided by the University Computing Center.

Publications: The Project has prepared, published, and distributed many reports, texts, and papers. This report contains information about this literature and its current availability.

Project Development and Finances: The history of the Project's development includes information about special programs, conferences, selection of participating faculty, and a financial statement.

Recommendations: The recommendations concern computing center services and organization, languages and hardware. Some guideline data on hardware requirements and computing costs should prove useful to schools contemplating a sizable computing effort at the undergraduate level.

In addition, the Final Project Report* contains nine "curriculum" reports prepared by faculty from the various engineering disciplines. These describe the extent of computer integration into curricula at The University of Michigan, faculty opinion of progress to date, and plans for the future. Each report includes several complete computer solutions to engineering problems for that discipline. In the nine reports there are 66 such problems which may be considered as supplements to the 56 problems already published in the First and Second Annual Reports of the Project.

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* Bound volumes consisting of this staff report and the individual curriculum reports are being distributed to engineering libraries. The staff and curriculum reports are available as separately published booklets.

During the years of Project activity, there has been a remarkable growth in computing work in the nation's engineering schools, dramatically emphasized by results of a recent Project survey. This survey shows that as of the fall 1962, approximately 30% of all engineering students attend schools which now have a required introductory computer course for undergraduates. Another 45% attend schools which require students in some (but not all) engineering disciplines to attend such a course. The Project's major goals have largely been met during these past few years. Although the time was obviously ripe for these developments, there seems little doubt that the Michigan Project and similar programs at other schools have played a major role in the rapid growth of computer work at the undergraduate level. The principal goal now is to intensify efforts, particularly in the area of faculty training. It is a virtual certainty that the trend toward required computer work at the undergraduate level will continue; we may expect that within a few years, essentially all engineering students will receive computer training before graduation.

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COMPUTER COMMITTEE AND PROJECT STAFF

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NAME	RANK	DEPARTMENT
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Glen V. Berg	Professor	Civil Engineering
Stuart W. Churchill	Professor, Chairman	Chemical and Metallurgical Engineering
Bernard A. Galler	Assoc. Prof.	Mathematics
William P. Graebel	Assoc. Prof.	Engineering Mechanics
Geza L. Gyorey	Asst. Prof.	Nuclear Engineering
Robert M. Howe	Professor	Aeronautical and Astronautical Engineering
George L. West	Assoc. Prof.	Naval Architecture and Marine Engineering
Dean H. Wilson	Lecturer	Industrial Engineering
Richard C. Wilson	Asst. Prof.	Industrial Engineering
Norman R. Scott, Vice-Chairman of Committee	Professor	Electrical Engineering
Donald L. Katz, Chairman of Committee	Professor	Chemical and Metallurgical Engineering

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THE USE OF COMPUTERS IN ENGINEERING EDUCATION

I. INTRODUCTION

In 1958 when this Project was conceived, it was evident to many engineering educators that the time had arrived for introducing computers more rapidly into the educational process. Researchers were finding the computer of great assistance in making laborious calculations and exploring new areas previously too complicated for consideration. Industry was making great strides in using computers for data processing and repetitive engineering calculations. A scattering of computer-oriented faculty, present in most engineering colleges, realized that if both students and faculty were equipped to use computers in course work, important additions to engineering education would be possible.

Many experienced engineering educators felt that the engineer's approach to problem-solving would be improved considerably by computer training. The computer's demands for precise definition of the problem-solving procedure (or algorithm) necessitate rigorous problem organization. Assumptions inherent in a problem-solving procedure should become more apparent. The parameter approach common to most computer algorithms should cause the student to focus attention on the structure of the general problem of which the problem at hand is simply a specific example. In short, many experienced people felt that computer training would develop in the student a broader view of the problem-solving process, and produce clearer thinking generally.

A survey of several engineering schools revealed, however, that there was no organized effort to accelerate the introduction of computers into the undergraduate instructional process. The University of Michigan was fortunate to receive a grant from The Ford Foundation to carry out this demonstration project of introducing computers into the instructional process.

During the four years since the Project was initiated, tremendous strides have been made in bringing computers into undergraduate engineering education. The Computing Center at The University of Michigan, for example, processed 8930 individual problems between April 27 and May 26, 1962. Of these, 2837 were generated by engineering students as a result of classroom problem assignments in 61 different engineering classes. In 1958, no school was known to be making an organized effort to integrate computer work into the engineering classroom; a recent survey by the Project shows we have progressed to the point where today some 30% of all engineering students are attending schools where all students are required to take a course in computer programming. Another 45% of all engineering students are at schools where some branches of engineering require at least an introductory course in machine computation. It appears that within the next few years all engineering students will learn how to use electronic computers as part of their required educational training.

In assessing the conditions which permitted this rapid introduction of a new tool and a new way of thinking into engineering education, one immediately recalls the early days of university computer use when most schools required that the computer user should be sponsored by an agency willing to pay for computer time. Many computing centers had to be self supporting. Gradually it became evident that in an educational environment, the people with ideas and work to be done are not necessarily only those with financial resources. By 1958 most schools were willing to permit the unsponsored educational use of the computer and were simplifying the paper work required to obtain permission to use the computer. Conditions which allowed an interested faculty member to use the computing facilities for instruction were necessary prerequisites for introduction of computer work into the educational process.

At the outset of the Project, three principal areas of activity seemed most significant. The first was the education of the engineering faculty so that teachers could use the computer themselves, judge its value by personal experience, and thus employ computer-related material in the classroom. The second was the study of methods of teaching students to program the digital computer and to use analog equipment. The third goal was to produce example problems to illustrate the use of computers in undergraduate engineering problem courses. As the Project developed, it was apparent that documentation of these efforts was a very important part of Project activities, for the written word was the mechanism by which information learned at The University of Michigan could be most effectively transmitted to other engineering schools.

Altogether, 56 faculty members from The University of Michigan College of Engineering participated in the various Project training programs. Over 120 example computer-oriented engineering problems with detailed solutions have been published. Many reports, texts, and other teaching aids for both faculty and students were prepared, published, and widely distributed by the Project.

The University also accepted responsibility for assisting in the instruction of faculty from other schools. To that end, two one-week workshops were held for 89 visiting engineering faculty members. Summer programs in 1960 and 1961 provided a two-month study program for 60 visiting faculty members. In addition, thirteen faculty members from other schools spent a full semester of study and work at the University. Altogether 160 faculty members from 65 American and Canadian engineering schools came to the University under Project sponsorship to study computing techniques and methods of utilizing computers in the engineering classroom. The experiences, opinions, and suggestions of these visitors during their participation in the Project's activities and later when they returned to their home schools were accumulated and implemented as part of the program. A survey of the activities of these Project participants after returning to their home schools is included in this report. Thus the experiences and recommendations of this report are, in effect, a collection of those gleaned from a large number of faculty from many schools in addition to The University of Michigan.

Although at the outset this Project was directed toward engineering education at the level of the accredited engineering schools, it soon became evident that the subject was also of interest to the physical and biological sciences, business, and many other fields. Likewise, schools of all types including secondary schools have become interested in computers. Even some elementary grades are exploring computer usage and associated mathematical and logical concepts. Thus, the experiences and recommendations resulting from the Project's work may reach beyond the area of engineering education alone.

This report details the experiences at The University of Michigan in introducing computers into the engineering classroom, starting with descriptions of the faculty training programs and of the introductory computer courses for students. Other topics that follow are the influence of developments in languages and computer hardware, the economics of processing student problems, the emerging role of university computing centers, and a historical review of the Project conducted at The University of Michigan.

This final report for the Project is published in two editions. One, the "library" edition, includes individual "curriculum" reports by faculty from the various engineering disciplines describing the introduction of computer work into their instructional programs, faculty opinions of such work, plans for the future, and a set of completely solved computer-oriented engineering problems suitable for classroom use. The other, a "staff" version (pages 1-83), is a summary report prepared by the Project staff without the detailed and voluminous individual curriculum reports. Those receiving the staff version of this report may obtain (as long as the supply lasts) separate copies of individual curriculum reports by writing the Project office.

II. TRAINING OF THE FACULTY

Faculty Training Programs

Three programs were developed to provide opportunities for engineering faculty members to become acquainted in various degrees with the use of computers in the classroom. For those without computer-related experience, workshops were held to give the teacher or administrator an opportunity to program two or three problems on a digital computer and to solve one or more problems on an analog computer. The goal of the workshops was to initiate and stimulate activity by the faculty member willing to do subsequent work on his own, or to acquaint administrators with the possibilities of machine computation in education.

The second program developed for teaching faculty was the nine-week summer workshop. These extended workshops provided a very thorough training of the participating faculty and some opportunity for them to develop abilities in solving problems of interest in their own subject areas or courses.

The third program instructed faculty during a regular semester by a series of scheduled lectures and work sessions, and personal tutoring. Information about computers was also disseminated through a series of weekly luncheons for any interested faculty.

One early important decision was the selection of the MAD (Michigan Algorithm Decoder) language for digital computer instruction. It was known that this language would not be generally available to most of the visiting faculty on returning to their schools; in fact, even now no such language is available. On the other hand, the language was believed to be superior and capable of demonstrating the power of a high-level procedure-oriented programming language and thus would provide incentive for faculty people to look forward to the use of a machine when such a language was available to all. Since this decision, MAD has become available at other engineering schools, although a broad spectrum of languages is in use throughout the nation.

Workshops

Two one-week workshops were held, September 5-10, 1960 with 59 in attendance, and September 4-12, 1961 with 42 participants. Given when most engineering colleges were in recess, these workshops provided opportunities for those who could not participate during the year.

The philosophy of the one-week workshop was to provide, in a short and intensive course, enough familiarity with computers to permit the participant to continue on his own to a fuller understanding of computing devices and their uses. However, these workshops appealed not only to those persons who would continue and become proficient with computers, but also to heads of departments, deans, and other administrators who wished to learn some of the capabilities of computers, knowing from the outset that they would probably not use them in their own work.

The workshops were planned around three digital problems of increasing complexity and one analog computer problem. The participants were first introduced to the computer language (MAD) in a series of lectures. Each day a number of simple drill exercises were assigned in work sessions before solution of one of the main problems was attempted. Several tutors were available to answer questions as they arose. A ratio of about two or three participants for each tutor is probably ideal, but this is difficult to attain in large workshops. A ratio of 5:1 was maintained in practice.

The best tutors for a faculty workshop are experienced students or faculty who are completely familiar with the language and are able to help others. It is imperative that tutors have a thorough understanding of the material to be covered, for confusion results when there are conflicting answers to the same question from two different tutors. Tutors should be encouraged to obtain running solutions to all problems before the workshop begins if at all possible.

Although participants in the workshop were permitted to keypunch their own cards, skilled keypunch operators were available at night so that minimal attention was given to mechanical details. As the University Computing Center operates its machine on a "closed shop" basis while programming is done on an "open shop" basis (In computer parlance "open shop" programming means that each user writes his own programs, while "closed shop" operation means that individual users are not permitted to operate the machine themselves.), details of computer operation are not discussed; "button pushing" should not be a part of such a workshop program. During the 1960 workshop, 58 participants used the IBM 704 a total of 235 times in solving three problems, yet a total amount of machine time of only three hours was used.

The concept of the workshop was not unique at Michigan and similar programs have been carried on successfully at many other schools. For instance, MIT conducted a similar workshop which was described by Professor C. L. Miller at a conference under Project auspices in Ann Arbor, September 11-12, 1960. It is believed that the attendance at the Michigan workshops by such a large number of faculty from other schools has caused many other schools to conduct their own faculty workshops.

Summer Programs

Nine-week programs were conducted in 1960 and again in 1961. Each summer program consisted of three full weeks of intensive work on programming the digital computer, one full week on the analog computer, and three weeks of part time work on numerical methods useful in machine computations (See Exhibit I). During the remainder of the time, each participant prepared example problems for use in his courses. Over 120 of these problems have been published in Project literature.

In 1960 there were 18 participants in the program taught by Elliott I. Organick and Brice Carnahan. The teaching materials (problems, etc.) of the 1960 program and those for the workshop as well, are not included in this report, since the 1960 program was similar in format to the 1961 programs described briefly below and in detail in the Second Annual Report of the Project.

In 1961, 45 faculty people from 29 different engineering schools and 10 from The University of Michigan took part in the program. E. I. Organick returned to Ann Arbor from the University of Houston to work with S. O. Navarro and Brice Carnahan, making a team of three instructors. The participants were divided into three groups, each working with one of the three instructors.

An advanced group of 14 persons (all of whom had had some programming experience) attended the lectures by B. Carnahan. This group worked a set of six difficult problems whose solutions (in the form of flow diagrams and MAD programs) are included as part of Appendix A of the Second Annual Report.

The other two groups, although taught separately by S. O. Navarro and E. I. Organick, followed the same schedule and shared lectures occasionally. People in these groups were learning to program for the first time. For this reason, a new feature, the use of some 200 programming exercises as a way of learning "small bits" of the total programming process, was incorporated into their program.

The participants studying with Drs. Navarro and Organick solved a set of seven problems. Statements of these problems, with solutions, are also included in Appendix A of the Second Annual Report. All except one of them are included in the revised A Computer Primer for the MAD Language written by E. I. Organick for use in the various training programs.

S. O. Navarro prepared a set of notes on the use of analog computers and gave the lectures on the subject. These were later revised and published by the Project as a text entitled Analog Computer Fundamentals. Each participant was asked to solve the series of analog exercises and problems shown in Appendix A of the Second Annual Report.

The first three weeks of numerical analysis lectures were given by Professor W. M. Kincaid of the Mathematics Department, assisted by Brice Carnahan, who prepared example problems. During the eighth week, R. C. F. Bartels, Director of the Computing Center, gave lectures on numerical solution methods for partial differential equations.

The outline for the numerical methods lectures and a description of the illustrative computer solutions prepared by B. Carnahan are included in Appendix B of the Second Annual Report. These notes on numerical methods consist of theoretical developments, numerical examples, flow diagrams for the procedures, and illustrative computer solutions.

EXHIBIT I

Schedule for the 1961 Summer Program

Week of	
June 19	Two hours of orientation. Sixteen hours of basic programming lectures for the three groups of participants. Ten hours of afternoon work sessions with assistants. Eight hours of evening work sessions (optional) with assistants. All participants were expected to have submitted solutions for the first four assigned problems by the end of the week.
June 26	Fifteen additional hours of programming instruction with emphasis on advanced topics. Eighteen hours of afternoon and evening work sessions. Participants were expected to have submitted all seven assigned problems by the end of the week.
July 3	Fifteen hours of lectures on various advanced topics such as executive systems, translator structure, interpretation of memory dumps, etc. Afternoon and evening work sessions continued as before. Lectures on the ACT III language for the LGP-30 were given for those interested. Tour of the Computing Center.
July 10	Twenty hours of lecture by Dr. Navarro on the analog computer. Afternoons devoted to laboratory work with the analog computer.
July 17 July 24 July 31	Eight hours per week of lectures on introductory and intermediate level topics in numerical analysis by Prof. W. M. Kincaid. During the weeks of July 17 and 24, about fifteen additional hours of instruction involving the presentation of examples by B. Carnahan. During the week of July 31, E. I. Organick presented a series of lectures on FORTRAN for various machines. Assistants were available during the afternoons, but there was no assigned work. Participants worked one sample problem of their own interest. No evening sessions.
August 7	Ten hours of lecture by R. C. F. Bartels on numerical solution of partial differential equations. In the afternoons and evenings an IBM 1620 (supplied by IBM for the week) was available for demonstration and operation by those interested.
August 14	No planned activities on August 14 and 15. Conference on August 16 and 17.

Special Lectures and Tutoring Program During the School Year

Beginning with the spring semester of 1960, groups of faculty members from The University of Michigan and other engineering schools participated in the Project, some on a full time, others on a part time basis. This program developed gradually over four semesters of operation and a total of 43 University of Michigan and 13 visiting faculty took part in it. Initially, the faculty attended the lecture series (to be described later) given primarily for students, but by the 1961-62 school year, special classes were held for participating faculty.

It should be noted that there were varying degrees of success with this program. Faculty members generally have many interests and unfinished projects at hand. Thus, when a professor is released from some of his teaching load to pursue a special study program he does not always choose to spend his extra time in such study. Also the active professor travels a lot, and misses many sessions of a lecture series scheduled at regular hours during the school week.

Results of Faculty Participant Questionnaire

In the spring of 1962 those faculty who participated in the workshop, summer, or semester programs were sent a questionnaire to determine the extent of their computer usage subsequent to their participation in Project activities. Results of the survey indicate that perhaps 80% of the faculty who had participated were highly motivated and continued to work successfully in the field. Others went back to their duties and found little time to pursue the matter further except, in some cases, by assisting others. Apparently there is still a large unfinished task of training faculty of engineering schools. This item was given by far the highest priority in the answers to questions about the major stumbling blocks to the successful incorporation of computers into the educational process (See Table I). The participants also gave high priority to the need for continued production of literature and information which would be of assistance to them in the instructional process (See Table II).

Although the questionnaires were not complete and some participants may have been modest in relating their contributions, it should be noted that several people who participated in the program are now in charge of computing centers servicing engineering faculty and students at their home institutions. Many are teaching an introductory computer course for engineering students. Others are chairmen or members of the computer committee in their college and are supplying the initiative to the computing programs at their schools. Table III summarizes the participants' activities after they returned to their home schools.

TABLE I

SUMMARY OF REPLIES TO THE QUESTION:* What do you consider the main stumbling block to increased use of computers in engineering courses at your school?

Answer	No. of Participants Who Gave This Answer		
	Non-Michigan	Michigan	Total
Lack of computer know-how by the faculty, faculty inertia, etc.	42	6	48
Lack of an adequate computer.	32	0	32
Lack of computer time for educational purposes. Too much "red tape" to request use of facility.	11	0	11
Lack of time in the curriculum.	11	3	14
Lack of time by the participant.	7	5	12
Lack of a required computer course.	16	1	17
	119	15	134

TABLE II

SUMMARY OF REPLIES TO THE QUESTION:* What activities by the Project would be of most assistance to you?

Answer	No. of Participants Who Made Comment		
	Non-Michigan	Michigan	Total
Would like additional literature, books and other information as it is developed.	37	3	40
Would like more documented sample problems with and without solutions.	29	2	31
Would like future meetings, refresher courses, etc.	19	9	28
Would like continuation of faculty training.	19	7	26
Would like more analog work.	7	1	8
	111	22	133

TABLE III

Summary of Participants' Activity in Computers in Engineering Education as Reported from Questionnaires

	Type of Participation	Workshop	Summer	Semester	Total
		No. of Participants			
	Type of Activity:				
Directing Teaching Using	Has major technical or administrative responsibility for integration of computers in his college.	2	5	0	7
Teaching Using	Has been teaching digital or analog computing to students or faculty.	14	18	7	39
Using	Has assigned problems involving digital or analog computers in required courses.	18	16	13	47
Using by Demonstration Only	Has used computer in class as demonstration only.	1	0	2	3
	None	11	3	4	18
	Total Persons Reporting	46	42	26	114

* 114 participants returned the questionnaire. Some gave more than one answer to this question.

TABLE IV

Number of Problems Worked by Participants Since Participation in Project

Number of Problems	No. of Participants Workshop	Summer	Semester	Total
None	7	5	4	16
1-4	24	17	15	56
5-10	5	8	4	17
> 10	10	12	3	25
Total	46	42	26	114

Another factor of interest to the Project staff was the relative effectiveness of the three methods of faculty training: the one-week workshop, the nine-week summer workshop, and a full semester of participation. This factor is measured at least partially by the number of problems worked by a participant since his return to his own college. The results from the questionnaire are shown in Table IV. This table seems to indicate that participants during the nine-week summer workshop were better equipped to formulate and work their own problems than were those who participated in a one-week workshop or even for a full semester. This is probably due to the intensiveness of the summer training and also to fewer outside faculty committments (committee assignments, etc.) during the summer months.

III. TEACHING OF THE STUDENTS

Three different approaches have been used at The University of Michigan for introducing undergraduate engineering students to the digital computer. 1) Initially a series of four two-hour,non-credit lectures was given. 2) Now, nine of the fourteen engineering programs (75% of engineering enrollment) require a sophomore level introductory digital computer course. 3) The Civil Engineering Department (9% of all engineering students) has elected to integrate initial computer instruction into the second of three required Geodetic Engineering courses, Surveying Computations (CE261).

The Civil Engineering Approach

The Civil Engineering approach at the University is outlined in considerable detail in Appendix C*, Use of Computers in Civil Engineering Education by Prof. H. J. Welch. Briefly,

* Note: Appendix C is included only in the hard cover bound copies of this report, but is available from the Project office as a separate curriculum report.

the computer-oriented portion of the semester's work (the course has three hours of credit: one hour of lecture and four hours of recitation or laboratory per week) is devoted to analytic geometry calculations for plane rectangular coordinate systems involving line-line, line-circle, and other types of intersections.

Students have been required to attend eight hours of non-credit introductory MAD lectures given by the Project's Assistant Director at the beginning of each semester. The student first encounters the computer early in the semester. He is assigned a set of geometry calculations to be solved on the desk calculator, and is required to punch his data and results on IBM cards. This packet of cards is given to his instructor who runs them on the computer with a "teaching machine program" described in Example Problem No. 76 (See Table XXXII). The program grades the results, notes errors, and assigns additional problems to be solved in case of error.

The second assignment involves the preparation of data for a checked-out program which is given to the student in punched card form, permitting him to become familiar with deck arrangement and Computing Center operating procedures. It also produces his first complete computer output. As part of the assignment, he must submit a flow diagram and discussion of the program.

The third and fourth assignments require the student to prepare completely the algorithm, program, and punched-card deck for two moderately complex geometry computations.

Mr. Welch feels that the inclusion of the introductory computer material in the course has not significantly reduced the amount of material normally covered, and that the approach is a fairly painless and rather successful way of preparing undergraduates for computer assignments in other engineering courses which follow in the junior and senior years.

Introductory Computer Course - Mathematics Department

Introduction to Digital Computing (Math 373) has been modified somewhat from the form shown in the Project's Second Annual Report, and will be described in more detail here. The one credit hour course requires two hours of classroom attendance per week, one for lectures by Bruce W. Arden of the Computing Center and Mathematics Department staffs, and the other for recitation conducted by teaching fellows and graduate assistants from the University Computing Center. The 450-500 students per semester are divided into two lecture and 13 to 16 recitation sections during the 1961-62 school year.

Mr. Arden's book, An Introduction to Digital Computing, prepared for publication in a preliminary edition by the Project staff, was available during the spring semester as the text for the course. The lecture topic sequence shown in Exhibit II closely follows the organization of the book. The early part of the semester is devoted to machine organization and languages and the latter part to numerical topics. Obviously all of these subjects cannot be covered in great detail in just 16 lecture hours. However, most can be introduced now that students no longer rely on lecture notes but have the aid of the text with its illustrations and sample programs.

The bulk of the language and programming material is covered in the recitation sections. The only language covered in detail and actually used by students to solve their problems is MAD, the procedure-oriented language developed at The University of Michigan.

Students are grouped into pairs and required to solve four problems on the computer during the semester. This involves all stages of the problem-solving process including algorithm formulation, program writing, card punching, submission for running on the computer until debugged (all done in pairs) and the writing of individual reports with the computer results. Graduate assistants are available at the Computing Center to answer general questions and assist students who are having program debugging problems. No programming is done for any student, and programs (which are not edited or otherwise examined by anyone but the student before and after running on the machine) can be rerun as often as necessary to check them out. Occasionally (usually when the assignment involves the writing of subroutines), after a student is satisfied that his program is working, he submits it for running with unknown data. These results are machine graded and returned directly to the instructor rather than the student.

The problems which were assigned during the fall and spring semesters of the 1961-62 school year are shown in Exhibits IIIa and IIIb. The problems for each semester are usually related to one another and results of completed assignments are used in the solution of later ones. The first problem is designed to introduce the student to the computer with as few statement types as possible (input-output, transfer, substitution and conditional statements primarily). Subsequent problems require the use of linear arrays, simple iterations, nested iterations and ultimately nested iterations with internal conditionals, compound conditional statements and multiple subscripts. Heavy emphasis is placed on the concept of a subroutine (external function) and inter-program communication through the calling sequence (argument list).

EXHIBIT II

Lecture Topics for Introductory Course in Digital Computation

1. Language and Notation:

   Language criteria, notation, relations, operators and precedence, the Turing machine as a language.

2. Elements of a Practical Language:

   The character set, constants, variables, expressions, statement labels, three basic MAD statement types.

3. Statements and Flow Charts:

   Iteration, conditional, input-output and declaration statements (MAD).

4. Functions and Example Programs:

   Arguments and bound variables, single value and vector functions, internal and external function (subroutine) definition forms.

5. Design of a Practical Machine:

   The Turing machine as a computer, design decisions for a practical machine, organizational structure of the 709/7090.

6. Machine Language and Components:

   Machine and assembly languages, physical description of machine components.

7. Number Systems and Arithmetic:

   Positional notation with emphasis on octal, binary, and decimal base systems, conversion from one base to another, complementing, scaling, floating point representation.

8. Computational Error:

   Formulation, truncation, round-off, measurement, generated, and propagated errors, range numbers.

9. Taylor Series and Divided Differences:

   Taylor series with error term, divided difference table, polynomial and error term.

10. The Solution of Equations:

    Newton's, Lin's, false position and half-interval root-finding procedures. Synthetic division and polynomial roots.

11. Additional Programming Topics:

    Higher dimensional arrays, vector initialization, relocatable programs.

12. Interpolation:

    Newton and Lagrange interpolation, forward, backward, and central differences.

13. Numerical Integration:

    Trapezoidal and Simpson's Rule, Gaussian Quadrature.

14. Simultaneous Integration:

    Elimination methods, triangular, diagonal, and augmented matrices, determinants, iterative solution methods.

15. Approximation:

    Least squares polynomials, Chebyshev economization.

16. Non-Numerical Problems:

    Searching and sorting algorithms, recursive functions, analytic differentiation.

EXHIBIT IIIa

Problem Assignments: Introductory Computer Course (Math 373)
Fall Term, 1961

1. Write a MAD program which, given the coordinates of the four end-points of two line segments, (X1,Y1)-(X2,Y2) and (X3,Y3)-(X4-Y4), where (X1,Y1) and (X2,Y2) are the endpoints of the first line segment and (X3,Y3) and (X4,Y4) the endpoints of the second, finds the coordinates of the intersection of the lines determined by the two sets of points. Print the given data and the coordinates (X,Y) of the point of intersection of the lines. Print NO INTERSECTION if the lines do not intersect.

2. Write an external function named INTER. which carries out the computation of problem 1 and, in addition to storing the coordinates of the intersection, directly returns an integer value 2 if the intersection is contained in both line segments, an integer value 1 if the intersection is not so contained and a zero if there is no intersection at all. The call for this function should be of the form

   INTER. (X1,Y1,X2,Y2,X3,Y3,X4,Y4,X,Y)

   where the symbols are as described in problem 1. It will be necessary to write a main program to test your function. After you are satisfied that the function is working properly, give the external function deck to your instructor for running with an unknown main program and data.

3. Write a main program which reads a sequence of N line-segment endpoints (i.e., the coordinate pairs of the endpoints) and then calls on the external function INTER. of problem 2 to determine and print which segments intersect and the coordinates of the points of intersection. In addition, print an "intersection matrix" where an element in the ith row and jth column is two if segment i and segment j intersect on the line segments, one if the intersection is not contained on the segments, and zero if there is no intersection. Note that this square matrix is symmetric about the diagonal which contains all zeros (a line cannot intersect itself) and either the upper or lower triangular pattern can be used. For this problem the input coordinates must be treated as elements of linear arrays. Although other arrangements are possible, four linear arrays X1, Y1, X2, Y2 are most convenient. With this arrangement the subscript indicates the segment number, e.g., the endpoint coordinates of the third segment would be

   X1(3), Y1(3), X2(3), Y2(3)

4. Write an external function having the calling sequence TRIANG.(A,N) where A is the name of an intersection matrix (integer) of the form produced in problem 3 and N is an integer whose value is the number of rows and columns in A. The function should print, in groups of 3 integers, the numbers corresponding to the line segments which form triangles. As in problem 2 the program should be tested with a simple calling program and, after checkout, given to your instructor for running with an unknown calling program and data.

Input-output operations are not greatly emphasized since it is felt that they are only incidental to the more important algorithm formulation. Input-output problems, which have in the past caused a sizable fraction of compilation and execution errors, have virtually been eliminated by the addition of several simplified input-output statements to the MAD language in September of 1961. These statements require neither formats nor the tedious character counting necessary in most programming languages and automatically produce labeled and scaled output values (the statements permitting the use of arbitrary formats are still available for those who wish to use them).

The time spent in solving the four problems of Exhibit IIIb and the number of computer runs reported by the students in one recitation section during the spring semester is shown in Table V. The addition of 30 hours of class time to the average of 34 hours spent on problems gives 4.3 hours per week per hour of credit, considerably above the nominal 3.0 hour load. In addition, extra time was spent in study of the text and lecture notes.

EXHIBIT IIIb

Problem Assignments: Introductory Computer Course (Math 373)
Spring Term, 1962

1. Write a MAD program which reads coordinate values for 3 points, (x_1,y_1), (x_2,y_2), (x_3,y_3) and fits them to a second degree equation of the form $a_0 + a_1x_1 + a_2x_1^2$. If any pair of abscissa values are equal, the comment "NO SOLUTION" should be printed. Otherwise solve the following set of simultaneous equations by determinants and print a_0, a_1, a_2, where

$$a_0 + a_1x_1 + a_2x_1^2 = y_1$$
$$a_0 + a_1x_2 + a_2x_2^2 = y_2$$
$$a_0 + a_1x_3 + a_2x_3^2 = y_3$$

2. Write an <u>external</u> <u>function</u> called EVAL. which computes as its <u>value</u> the expression

$$p(z) = a_0 + a_1z + a_2z^2$$

The given arguments in order are X, Y, I, Z, S where X and Y are linear arrays of paired data values (x_j,y_j) and the values a_0, a_1, a_2 are evaluated by determinants as in problem 1 for the points (x_{i-1}, y_{i-1}), (x_i,y_i), (x_{i+1}, y_{i+1}). Z is an argument which can be considered as abscissa for interpolation using the second degree polynomial which passes through the three points. If any of the abscissas are identical, the computation should not be carried out and the function should transfer to the statement labeled S. It will be necessary to write a main program to check out the function. After you are satisfied that the function is correct, give the deck to your instructor for running with an unknown calling program and data.

3. Write a main program which reads an integer N, the ordered array $x_0, x_1,\ldots,x_N$, an array of corresponding data values $y_0, y_1,\ldots,y_N$, and then several values for the variable z. For each z the "closest" x_i should be used wherever possible, as the central point in a three-point interpolation using the function EVAL. as in problem 2. Print the x_i,y_i data, z, and the resulting value for p(z).

4. Write an <u>external</u> <u>function</u>, called INTERP., whose arguments in order are: X, Y, I, Z, N, S. The direct result is the <u>value</u>

$$p(z) = a_0 + a_1z + a_2z^2 + \ldots + a_nz^n$$

where p(z) is the nth degree polynomial which passes through the points (x_i,y_i), $(x_{i+1},y_{i+1}),\ldots,(x_{i+n},y_{i+n})$. The function SLEQ.(M,A) may be called from the library tape to solve the simultaneous equations where M is the integer number of equations and A is the augmented matrix of linear equation coefficients. The determinant of the array of coefficients (MXM) is returned as the <u>value</u> of the function and the solution values (the a's) are placed in order in the (M+1)th column of A. As before, the statement labeled S should be executed if it is impossible to compute $a_0,a_1,a_2,\ldots,a_n$. It will be necessary to write a main program to test the function and the deck should be handed in as for problem 2.

TABLE V

Study of Time and Number of Computer Runs for One Section of 26 Students on Solutions of Exhibit IIIb

Math 373 Problems: Spring Semester, 1962

Problem Number	Time, hours			Number of Computer Runs		
	Min	Avg	Max	Min	Avg	Max
No. 1	5	10.4	25	1	3.1	5
No. 2	2	5.7	15	1	2.4	4
No. 3	2	5.7	9	1	2.3	4
No. 4	4	12.1	25	1	3.2	7
		33.9			11.0	

Special Lecture Series

As mentioned previously, an evening lecture series primarily for students (but open to anyone interested) has been given each semester since the initiation of the Project in the spring of 1959. Initially only a few students had taken a formal computer course and therefore most of those attending had had no training in programming methods. In later semesters most of those attending appeared to be transfer students, particularly graduate students, and others who already had some computer training but needed to review the material. The lecture series is composed of three two-hour lectures given at weekly intervals followed by a problem assignment. Students are invited to program one problem for submission to the computer. A fourth lecture is given two weeks later in which a problem solution is presented and individual student solutions discussed. A schedule of the lecture series is shown in Exhibit IV.

Since the beginning of the lecture series, attendance has ranged from 250-400 students with about 100 of these submitting a problem to the computer each semester. Mature students with a desire to learn are given sufficient orientation to begin a self-study program to become acquainted with programming techniques. It has been found that faculty and graduate students from non-engineering departments are also attending the lectures. The series will continue each semester as long as attendance is significant and until it is customary for all undergraduate students at all engineering schools to have computer training. In due time formal class work will fulfill the need and the lecture series will be discontinued.

EXHIBIT IV

Schedule for Introductory Computer Lecture Series

First Week:

An introduction to computer hardware, machine organization, computer languages, flow charts, and the MAD language (modes, constants, variables, arithmetic operators, arithmetic expressions, and the substitution statement).

Second Week:

Subscription, function references, relations, Boolean operators, Boolean expressions, statement labels, the transfer statement, the conditional statements, the simplified input and output statements.

Third Week:

The iteration statement, dimensioning and presetting arrays, the MAD statement card format, preparing a program for running on the University's IBM 7090 computer. All those attending the lectures are given the opportunity to write a MAD program to solve a problem which is handed out at this session. The assigned problem is designed to be a familiar one which requires use of all essential features of the language. A problem used recently called "The Automatic Professor" involves a program which reads a variable number of quiz grades, a final grade, and some pupil identification and then assigns a letter course grade to the student depending on the final weighted numeric grade. The program is keypunched and run on the 7090 computer for the student.

Fourth Week:

No formal lecture. Assistants are available to help those who have any questions about programming the assigned problem.

Fifth Week:

The punched MAD program and printed results from the machine are returned to those who programmed the assigned problem. The computer output is described in detail. Operating procedures used at the Computing Center, and, if time permits, internal and external functions and other features of the MAD language are discussed.

The Lecture Machine

As the number of students using the University's Computing Center increased rapidly from semester to semester, a great deal of repetitive instruction was required to train students in procedures for operating keypunches and other mechanical card and paper handling equipment. Two portable "lecture machines"* were purchased by the Project to allow a prepared lecture to be played back repeatedly at any time, relieving Computing Center staff from the tedious task of routine training. The machine may be played continuously or on demand by pushing a button. It has been

* The machines consist of a stereo magnetic tape recorder with associated amplifying equipment which can accommodate a talk of up to 45 minutes in length on one recording channel. On the second channel, impulses can be recorded at appropriate places during the talk to automatically sequence a slide projector containing a 40 slide cartridge. The machine projects the slides onto the rear of a rectangular daylight screen (2-1/2 ft × 3 ft). The entire unit, custom-built by Busch Film and Equipment Co., Saginaw, Michigan, is self-contained in a large cabinet and resembles an oversized television set. One of the machines is automatic to the extent that once a complete performance is finished, the tape is rewound and the slide cartridge repositioned for the next showing.

found that the lecture machines are being used almost continually at the beginning of each semester thus saving the time of assistants and Computing Center personnel. In the future, one of the machines will be used primarily for keypunching instructions and the other for the remainder of the mechanical handling of cards and paper. It is expected that lectures on introducing elements of computer programming, descriptions of Computing Center operating procedures, etc., will also be put on the machines as alternate programs.

Who Will Teach the Introductory Computing Course?

Colleges with long established computing centers (usually operated by mathematicians) generally rely on guidance from or direct participation by this group in presenting the introductory computer course. In such cases the introductory course lectures tend to be only partially programming per se and often include mathematical topics such as numerical analysis. Advanced graduate students and young instructors who are the most likely group to have detailed knowledge of programming and who are competent in the field of mathematics as well, may be expected to handle the multiple recitations or laboratory sections of computer courses. Engineering faculty who are well informed in mathematics and machine computation may be an excellent alternate source of these teachers.

Those engineering schools which have moved into the computing area without benefit of computing center mathematicians are generally evolving courses which concentrate to a greater extent on programming. Discussion of numerical analysis, for example, is usually reserved for special mathematics courses to be elected later. In the future, numerical topics may well be included in some of the advanced engineering courses, just as other mathematical topics are now incorporated into many upper level engineering offerings.

The Structure of Required Programming Courses

A survey of engineering school deans (discussed in detail in section IV) concerning courses in programming or introductory computing techniques indicates a definite trend towards required courses. Faculty with training in machine computation and familiar with programming generally agree that formal presentation with careful laboratory supervision is the best way of imparting such knowledge to undergraduate students. The direction these courses will take in the future will vary from institution to institution because of different personnel and circumstances.

The results of the deans' questionnaire shown in Table VI indicate that as of September 1962 some 30.6 percent of all engineering students are enrolled in engineering schools where all students are required to take an introductory computer course. An additional 44.9 percent are enrolled in other schools where at least one department (usually several) requires all of its students to take such a course.

The number of credit hours, the level, and the academic background of the faculty member or members responsible for teaching these courses are shown in Tables VIIa and VIIb. Table VIIa describes the courses at 42 schools which now require all students to take an introductory course. It shows that such courses are given predominantly at the freshman or sophomore level for one, two, or three credit hours; the teachers are predominantly from the computing center or associated with individual engineering departments.

Table VIIb shows that at 50 other schools requiring some (but not all) students to take an introductory computer course, such courses are usually given for three hours at the junior level by engineering faculty. In many cases, deans of schools in this category indicated that plans for a college-wide required course for few hours credit at an early level were being prepared. It should be noted that, even at schools where no plans for a required course are being considered, there may be a considerable emphasis on computer training via informal non-credit or elective courses.

The detailed results of the deans' questionnaire on a school by school basis are shown in Table IX.

TABLE VI

Results of Deans' Survey on Introductory Computing Courses at ECPD Schools

Nature of Course	No. of Schools	No.* of Students	% of All Engineering Students++
Required-All Depts.	42	53051	30.6
Required-Some Depts.	50	77922	44.9
Not Required but Study Under Way	42	37928	21.8
Not Required and No Study Under Way	9	4620	2.7
Subtotal	143**	173521+	100.0
No Reply	21	24150	
Total	164	197671	

* Based on 1961 Fall Term Enrollments
** 87% of Total
\+ 88% of Total
++ These percentages are computed using a total of 173521 students accounted for by the replies, and should approximate true figures considering students at schools not accounted for (24150) as well.

Introductory Computer Courses at ECPD Schools

TABLE VIIa
Where All Departments Require the Course

Year	Credit Hours 0	1	2	3	4	Unspec.	Total
Freshman	5	5	3	1			14
Sophomore	1	4	3	5	2		15
Junior		1	2	2	1		6
Senior				2			2
Unspecified						5	5
Taught By:							
Math.		1		3	1		5
Comp. Center	3	2	4	4			13
Engr.	3	6	4	3	2		18
Unspecified		1				5	6
Total	6	10	8	10	3	5	42

TABLE VIIb
Where Some (But Not All) Departments Require the Course

Year	Credit Hours 0	1	2	3	4	Unspec.	Total
Freshman			1	2			3
Sophomore		7	5	3	5		20
Junior			1	13	1		15
Senior		2		6			8
Unspecified					1	3	4
Taught By:							
Math.		2	1	5	1		9
Comp. Center		2	3	3			8
Engr.		5	3	16	6	1	31
Unspecified						2	2
Total	0	9	7	24	7	3	50

As shown by the outline of the introductory computer course at The University of Michigan (See Exhibit II), numerical topics are used as the vehicle to teach the programming language. The reasoning behind this marriage is that numerical examples also happen to be good programming examples, and by merging the two the student learns additional material which later will be of value in other technical courses. On the other hand, the addition of the numerical topics demands more outside reading and study by the student and requires a total time which may not be justified in light of the one hour of credit given.

In the Civil Engineering Department at Michigan, the preferred marriage is between surveying computations and programming. At many universities the programming topics are treated separately in courses of one or two hours.

Since each school has a different situation in terms of the number of credit hours available for the required course, the background of the lecturer, and the relation of the programming course to other courses in the curriculum, it is difficult to recommend any one approach for the structure of the required programming course.

However, based on experiences at Michigan and the comments and responses of engineering school deans, several concepts appear to have gained wide acceptance:

1. Computer training involves more than technique; the training assists the student in the organization, analysis, and synthesis required for the logical solution of engineering problems. The computer can thus be considered an <u>educational</u> tool as well as an <u>engineering</u> tool.

2. Communication with the computer should be via a formal procedure-oriented language to minimize the machine-oriented aspects of computer use and at the same time to emphasize flow diagramming and algorithm construction, i.e., to focus primary attention on the problem-solving process. The same language should be used throughout a university to simplify inter-student and inter-departmental communication. It should be noted that the training in flow diagramming techniques will prove of value in many problem courses in engineering, even when the computer is not being used.

3. Engineering students should be introduced to computing techniques early in their undergraduate training, preferably in the freshman or sophomore years.

4. The student should gain additional computer programming experience in subsequent problem courses at the junior and senior levels so that by graduation he will have acquired a familiarity and a competence in communicating with computers which will pay immediate dividends in a career in industry or research.

Some key factors which appear to have contributed to recent acceleration of computer acceptance in the curriculum are:

1. Procedural language concepts have reached maturity.
2. Hardware is more available.
3. Fast processors and time-saving executive systems have been developed. These enabled cost per student problem to drop within reach of most schools.
4. Literature aimed at the level of the beginning student rather than the computing expert gradually became available.
5. Significant numbers of faculty received computer-oriented training via programs such as the Michigan Project, NSF Institutes, local workshops, attendance at advanced level computing courses at their universities and, in some cases, self-instruction.

Some of these topics will be discussed independently in later sections.

A Growing Responsibility of Small Liberal Arts and Junior Colleges

A sizable number of students matriculate in the large engineering schools as transfer students from numerous small liberal arts and junior colleges. It is clear that these smaller schools will have to assume the responsibility of providing some instruction in introductory computing techniques in order to prepare their students for transfer to engineering schools at the junior level.

Many small schools already have begun computer instruction. A growing number have small computers and normally at least one enthusiastic faculty member who takes responsibility for the program. But many schools are out of touch with latest developments in computer instruction, especially as applied to engineering education. Of the small schools which now have computers, many still emphasize machine-level languages instead of the more powerful procedure-oriented ones.

It would appear that major engineering schools maintaining or associated with first-rank computing facilities must take the initiative in providing the needed assistance to show the way to the feeder institutions and provide needed service at reasonable cost. It is reasonable to expect that some computer instruction will be offered in most first rate high schools in the near future. Should this occur, a need for faculties of the junior colleges to provide assistance in computer training for local community high school programs will very likely develop.

Related Mathematical Topics for Advanced Students

Engineers who are making progress in using computers to solve their research problems often find it necessary to learn new topics in mathematics. Many of these fall under the general heading "Numerical Analysis." In addition, there are other subject areas which the professor, graduate student, or research engineer may find it necessary to understand in order to solve his particular problem on the computer. A list of some such topics, not comprehensive in scope, is given in Table VIII.

The trend is clear. More and more of our faculty and graduate students will need to become familiar with new mathematical tools and techniques; gradually this material will filter down into the undergraduate program. Adjustments in the mathematics curriculum will very likely accompany this process. New courses will certainly be developed. Students who do not necessarily expect to become computer specialists, but who plan to work at a high level of achievement in the applications area, e.g., certain Ph.D. and M.S. students whose research success depends on results of a substantial computation effort, ought to take such courses if available.

Certain topics in numerical mathematics are already considered critically important. In the summer of 1962 the Project arranged for an applied mathematician and two engineers to assemble problem statements, instructive algorithms and illustrative computer problems covering most of the common numerical methods. The result of their effort is described in more detail later (See section VII).

TABLE VIII

Important Mathematical Topics for Advanced Engineering Students

Numerical Analysis

1. Interpolation and numerical integration (the notion of finite differences).
2. Approximation methods such as least squares and Chebyshev economization.
3. Solution of nonlinear algebraic and transcendental equations.
4. Solution of linear systems by elimination techniques (beginning matrix theory) and iterative techniques (advanced matrix theory).
5. Characteristic value determination.
6. Ordinary differential equations; solution by single- and multi-step digital methods, and analog computer techniques.
7. Partial differential equations, including solution by several digital techniques, and by analog and analog-digital hybrid machines.

Mathematical Programming

1. Linear Programming (by the simplex or product form methods).
2. Dynamic Programming.
3. Calculus of Variations.

Concepts and Applications in Statistics and Probability

1. Elementary statistical theory.
2. Significance tests, correlation techniques, regression analysis.
3. Probability theory and computation, modeling of stochastic processes.

Analog Computation

For several years prior to the organization of the Project, The University of Michigan had considerable experience in analog computation through the Instrumentation group in the Department of Aeronautical and Astronautical Engineering. Several courses in that Department regularly used analog computers to solve problems in laboratory sessions. The Electrical Engineering Department had also included the use of analog computers in some of its courses. During the spring semester and the summer of 1960 the Project arranged for the Aeronautical Department staff to give faculty lectures on analog computation and to provide opportunities for engineering faculty from all departments to use their computers. Later, equipment was purchased by the Project for use by faculty and students in the form of five Applied Dynamics and three Reeves analog computers. Each analog machine is equipped with eight amplifiers, four of which may be used as integrators, and with dual-channel Sanborn hot wire recorders. An X-Y plotter, a signal generator, and some non-linear equipment such as function multipliers were added to give versatility to the equipment. The several small machines were selected to permit students to work in pairs rather than in larger groups. The laboratory has been organized so that any faculty member in the College can request use of the laboratory during his classroom meeting time; the students meet in the laboratory and solve their assigned problems. The Project employed graduate assistants to make most effective use of the laboratory, give in-class demonstrations, and keep the machines in running order. On one occasion a Project assistant took a portable analog unit equipped with a display oscilloscope to all of the differential equations classes in the Mathematics Department to illustrate the use of the analog computer in solving differential equations.

A larger Applied Dynamics AD-64 analog computer was also purchased for handling more difficult problems. It has 24 amplifiers, a number of nonlinear components, and a repetitive operation mode, an important feature for classroom demonstrations.

The example problems prepared for the various disciplines (See Table XXXII) include several on the use of analog computers to solve engineering problems. A large number of engineering students are taking courses in which solution of an engineering problem on the analog computer is required.

IV. SURVEY OF PROGRESS IN INTRODUCING COMPUTERS INTO ENGINEERING EDUCATION AS OF FALL, 1962

In the spring of 1962, the Project sent a questionnaire to deans of all engineering schools in the United States and Canada (see Table XXXI). The questionnaire is shown as Exhibit V.

The Project received excellent cooperation from the engineering deans with 166 replies to the 189 questionnaires mailed out, a response of 87.8 percent.

An overall summary of the responses of the accredited American schools appeared earlier in Tables VI, VIIa and VIIb.

EXHIBIT V

The Deans' Questionnaire

1. Has your College decided to require undergraduate training in introductory computing techniques or computer programming in some or all of its engineering curricula?

   Yes___ No___

2. If the answer to question 1 is No, is there a study of the question currently in progress?

   Yes___ No___

3. If the answer to question 1 is Yes, please answer the following:

   a. Does the requirement apply to the entire engineering college, or only to some departments?

   All___ Some___

   b. If the answer to part a is All, please indicate the date when decision was (or is to be) implemented.

   Date__________

   c. If the answer to part a is Some, please indicate the departments and the associated implementation date.

Department	Date Decision Implemented

4. Please indicate the nature of your required training giving the kind of course, its level and credit, if any, and the name of the individual who now teaches or who will teach this material. We may write to this individual for further details. If more than one such course is used at your school, please let us have the names of each individual involved in teaching the material.

Course Name and Number	Instructor	Credit Hrs. Sem.	Credit Hrs. Qtr.	Level Fr.	Level Soph.	Level Jr.	Level Sr.

5. Other Comments:

____
Signature of Dean of Engineering

____
School

Status of Required Computer Instruction: Result of Deans' Questionnaire

Table IX below lists in detail the answers to the questionnaire given by the Deans of Engineering. In addition, the number of faculty members from each school who have taken part in various Project study programs and the fall 1961 enrollment for all ECPD schools are shown as well. Where any additional pertinent information was supplied by a dean, comments (in many cases a list of departments at the schools which do have required courses) are written in the last column. Most schools which do not plan to have required computer courses do have an elective course available. Where specified, the level and credit hours for these courses are included in the listing.

Key to Table:

In column 6 of Table IX, the letter A indicates that all engineering departments require computer training, S indicates that some departments require such training, N that no department requires training, and * indicates that the questionnaire was not returned. In column 7, which contains an entry only for schools where no department currently requires computer training, a Y or N indicates respectively that there is or is not a study of a possible required course under way. The number of credit hours and the academic level at which the computer course is taught are shown in columns 8 and 9. Column 10 indicates the background of the faculty person responsible for teaching the course, (M-Mathematics, C-Computing Center, E-Engineering). The letter U in columns 8, 9, or 10 indicates that the questionnaire was returned but that the pertinent information was not given.

TABLE IX

Listing by School of Replies to Deans' Questionnaire

Engineering School	No. of Project Participants: Semester	No. of Project Participants: Summer	No. of Project Participants: Workshop	No. of Undergraduate Students in ECPD Schools-Fall 1961	Is there a required course?	If no, is there a study?	Credit Hours	Course Level (Year)	Faculty in Charge	Remarks
Column 1	2	3	4	5	6	7	8	9	10	11
Air Force Institute of Technology	0	0	0	85	N	Y	4	3	M	
U. of Akron	0	0	0	445	A		3	2	C	
U. of Alaska	0	0	0	157	A		3	4	M	ChE, CE, EE, IE, ME
U. of Alabama	0	0	0	2152	S		3	3	M	IE
U. of Alberta	0	4	4		S		2	3	C	CE, EE, ChE, Petr, ME
Alfred Univ.	0	0	0	331	N	Y	U	U	U	
Antioch College	0	0	0	54	*					
Arizona State U.	0	0	0	959	*					
U. of Arizona	0	0	0	1471	A		1	2	E	
U. of Arkansas	0	0	0	1033	S		3	3	M	IE, ME, EE, ChE
Auburn U.	0	0	0	1106	S		5	2	E	Indus. Management
Bradley U.	0	0	0	650	*					
Brigham Young U.	0	0	0	729	*					
U. of British Columbia	0	0	0		S		2	3	M	
Polytechnic Inst. of Brooklyn	0	0	0	2492	S		3	3	E	CE, EE, IE
Brown U.	0	0	0	225	*					
Bucknell U.	0	0	0	424	A		1	1	C	
U. of Buffalo	0	0	2		A		3	3	C	
California Inst. of Technology	0	0	0	235	N	N	U	U	C	Informal Instruction
U. of California-Berkeley	0	1	3	2107	S		U	U	E	CE, EE, IE, Mineral
U. of California-Davis	0	0	0	156	N	N	U	U	U	Elective
U. of California-Los Angeles	0	1	0	1057	A		U	1	C	Non-Credit Lab.
U. of California-Santa Barbara	0	0	0	66	*					
Carnegie Inst. of Technology	0	3	1	1779	S		2	2	C	ChE, CE, EE
Case Inst. of Technology	0	0	0	759	A		3	2	M	
Catholic U. of America	0	0	0	308	N	Y	U	U	U	

TABLE IX, Continued

Engineering School	No. of Project Participants: Semester	Summer	Workshop	No. of Undergrad. Students in ECPD Schools-Fall 1961	Is there a required course?	If no, is there a study?	Credit Hours	Course Level (Year)	Faculty in Charge	Remarks
1	2	3	4	5	6	7	8	9	10	11
U. of Chattanooga	0	0	0		N	N	U	U	U	
U. of Cincinnati	0	0	0	3032	N	Y	2	4	C	
The Citadel	0	0	0	386	N	Y	U	U	U	
Clarkson College of Technology	0	0	1	958	*					
Clemson College	0	0	0	1578	S		2	3	M	IE
Colorado School of Mines	0	0	0	943	N	Y	U	U	U	
Colorado State U.	0	0	0	686	N	Y	U	U	U	
U. of Colorado	0	0	0	2697	S		3	4	M	Appl. Math.
Columbia U.	0	0	0	446	N	Y	U	U	U	
U. of Connecticut	0	0	1	1100	N	Y	U	U	U	
Cooper Union	0	0	0	694	A		2	2	E	Engr. Courses
Cornell U.	0	0	1	1930	A		3	2	M	
Dartmouth College	0	0	1	99	A		3	3	C	
U. of Dayton	0	0	0	987	N	Y	3	3	C	
U. of Delaware	0	0	0	541	S		3	2	E	CE,EE,ChE,ME
U. of Denver	0	0	1	322	N	Y	1	3	E	
Detroit Inst. of Technology	0	0	1		N	Y	U	U	U	
U. of Detroit	0	0	4	1837	A		U	U	U	
Drexel Inst. of Technology	0	0	1	4092	*					
Duke U.	0	0	0	451	*					
Ecole Polytechnique	0	0	0		S		4	4	E	EE, Engr. Physics
Farleigh Dickinson U.	0	0	0	2448	*					
Fenn College	0	0	0	1506	N	Y	U	U	U	
U. of Florida	0	0	0	2011	S		3	3	E	ChE,EE,ME,IE
George Washington U.	0	0	0	576	N	Y	U	U	U	
Georgia Inst. of Technology	1	1	1	3626	*					
U. of Georgia	0	0	0	64	N	N	U	U	U	
U. of Hawaii	0	0	0	903	A		4	3	E	
Harvard U.	0	0	0	117	S		3	1	C	San. Engr.
U. of Houston	4	4	4	1230	A		2	2	C	
Howard U.	0	0	0	555	N	Y	3	3	P	Physics
U. of Idaho	0	0	0	751	N	Y	U	U	U	
Illinois Inst. of Technology	0	1	0	3632	N	Y	U	U	U	
U. of Illinois	0	3	2	5293	S		3	2	M	EE,AE
Indiana Technical College	0	0	1		A		3	3	C	
Iowa State U.	0	0	1	2852	A		1	1	E	
State Univ. of Iowa	1	1	1	580	N	N	3	4	C	Elective
Johns Hopkins U.	0	0	0	1536	S		4	2	E	EE
Kansas State U.	0	0	0	1289	N	Y	2	3	M	
U. of Kansas	0	0	0	1191	N	Y	U	U	E	
U. of Kentucky	0	0	2	1454	S		2	2	C	ME,EE
Lafayette College	0	0	0	541	A		3	4	E	
Lamar State College of Tech.	0	0	0	1045	A		1	1	E	
Laval Univ.	0	0	0		S		2	4	E	EE,Physics
Lawrence Inst. of Technology	0	0	1		A		3	2	C	
Lehigh U.	0	0	3	1264	S		3	3	M	EE,CE,IE,Engr. Mech.
Louisiana Polytechnic Inst.	0	0	0	838	N	Y	3	2	E	
Louisiana State U.	0	0	1	925	*					
U. of Louisville	0	0	1	640	A		1	2	M	
Lowell Technological Inst.	0	0	0	422	S		3	4	E	EE,ME,TE
U. of Maine	0	0	0	970	S		2	2	E	ME,CE
U. of Miami	0	0	0	790	S		1	2	E	CE,EE,IE
Manhattan College	0	0	0	1121	S		1	2	E	EE,CE
U. of Manitoba	0	0	0		S		3	4	E	
Marquette U.	0	0	0	1403	S		4	2	E	EE
U. of Maryland	0	0	0	1985	S		U	U	U	

TABLE IX, Continued

Engineering School	No. of Project Participants: Semester	No. of Project Participants: Summer	No. of Project Participants: Workshop	No. of Undergrad. Students in ECPD Schools-Fall 1961	Is there a required course?	If no, is there a study?	Credit Hours	Course Level (Year)	Faculty in Charge	Remarks
1	2	3	4	5	6	7	8	9	10	11
Massachusetts Inst. of Tech.	0	0	0	1329	S		2	1	C	CE
U. of Massachusetts	0	1	1	928	S		3	3	E	IE
McGill U.	0	0	0		S		U	5	C	EE
Mich. College of Mining and Tech.	0	0	0	2016	S		1	2	C	Mining,ME,EE,CE
Michigan State U.	0	0	0	1547	A		U	U	U	
U. of Michigan	44	12	11	3073	S		1	2	M	ME,EE,ChE,Met,IE,CE,N
U. of Minnesota	0	0	0	2484	*					
Mississippi State U.	0	0	0	1306	N	Y	3	4	E	EE,ME,AE,ChE
Missouri School of Mines & Met.	0	1	0	2740	S		1	2	M	M,CE,EE,ME,ChE
U. of Missouri	0	0	0	1383	S		3	3	M	ME
U. of Mississippi	0	0	0	317	A		1	1	E	
Montana School of Mines	0	0	0	243	N	N	U	U	U	
Montana State College	0	0	0	893	N	Y	U	U	U	
U. of Nebraska	0	0	4	1185	A		0	1	C	Nine lecture hours
U. of Nevada	0	0	1	486	N	Y	U	U	U	
Newark College of Engineering	0	0	0	3051	S		3	3	C	CE
U. of New Brunswick	0	0	0		S		U	4	E	EE,ChE,ME,Surveying
U. of New Hampshire	0	0	0	465	N	Y	U	U	E	
New Mexico State U.	0	0	1	1264	N	Y	U	U	U	
U. of New Mexico	0	0	1	764	S		3	4	E	CE,EE,ME
New York U.	2	0	1	1217	S		U	U	U	IE,EE
City Univ. of New York	2	5	4	4406	S		3	3	E	ChE,CE,ME
North Carolina State U.	0	0	0	3275	S		3	4	E	IE,EE
A.&T. College of North Carolina	0	0	0		*					
North Dakota State U.	0	0	0	813	S		3	3	M	EE
U. of North Dakota	0	0	0	520	S		1	2	C	
Northeastern U.	0	0	0	2992	A		4	2	M	
Northwestern U.	0	0	0	772	S		4	2	E	IE
Norwich U.	0	0	1	311	*					
Notre Dame U.	0	0	0	1197	S		2	2	E	ChE,ME,CE
Nova Scotia Tech. College	0	0	0		S		U	5	M	EE,CE
Ohio Northern U.	0	0	0	209	A		U	U	U	
Ohio State U.	0	3	0	2737	A		3	3	E	
Ohio U.	1	1	0	969	S		1	2	E	EE
Oklahoma State U.	0	0	0	1873	A		0	2	E	One hour per week
U. of Oklahoma	0	1	0	1705	S		3	3	C	IE,ME,Gen,Engr.Physic
Oregon State College	0	1	0	1388	N	N	3	3	M	Elective
Pennsylvania State U.	0	0	0	2884	A		0	1	E	One hour per week
U. of Pennsylvania	1	1	2	428	S		3	4	E	ChE,EE,ME
U. of Pittsburgh	0	0	0	1617	S		3	3	E	ChE,EE,IE
U. of Portland	0	0	1		A		2	2	C	
Pratt Institute	0	1	0	569	S		1	4	E	ChE,ME,IE
Princeton U.	0	0	0	470	N	N	U	4	E	Elective
U. of Puerto Rico	0	0	0	1875	*					
Purdue U.	0	7	10	6051	A		2	3	C	
Queens U.	0	0	0		N	Y	U	U	C	
Rensselaer Polytechnic Inst.	0	1	0	2001	S		2	2	E	CE,EE,ME
U. of Rhode Island	0	0	0	674	N	Y	U	U	U	
Rice U.	0	0	1	573	A		4	2	E	
U. of Rochester	0	0	0	272	S		3	4	E	ChE,ME
Rose Polytechnic Inst.	0	1	0	411	A		2	1	E	
Rutgers U.	0	0	0	835	A		U	U	U	Preparing course
St. Louis U.	0	0	0	639	N	Y	3	4	M	
San Jose State College	0	1	0	1302	N	Y	U	U	U	

TABLE IX, Continued

Engineering School	No. of Project Participants: Semester	Summer	Workshop	No. of Undergrad. Students in ECPD Schools-Fall 1961	Is there a required course?	If no, is there a study?	Credit Hours	Course Level (Year)	Faculty in Charge	Remarks
1	2	3	4	5	6	7	8	9	10	11
U. of Santa Clara	0	0	0	272	S		1	4	E	EE
U. of Saskatchewan	0	0	0		S		1	4	E	CE, ChE, Agric., EE
Seattle U.	0	0	0		S		2	3	E	
U. of South Carolina	0	0	0	697	A		1	2	U	
U. of Southern California	0	0	1	988	A		1	3	E	
S. Dakota School of Mines & Tech.	0	0	1	725	N	Y	1	3	E	
Southern Methodist U.	0	0	0	485	N	Y	3	3	E	
S. Dakota State College	0	0	1	633	A		2	1	C	
Southern Illinois U.	0	0	1		*					
U. of Southwestern Louisiana	0	0	0	643	A		U	U	U	
Stanford U.	0	2	0	873	N	Y	3	4	E	
Stevens Inst. of Technology	0	0	0	862	A		1	1	C	
Swarthmore College	0	0	0	77	N	Y	U	U	U	
Syracuse U.	0	0	0	550	*					
Tennessee A.&I. State U.	0	0	1		*					
U. of Tennessee	0	0	0	2062	*					
A.&M. College of Texas	0	2	0	2282	S		4	3	E	IE
Texas College of Arts & Industries	0	0	0		A		3	2	E	
Texas Technological College	0	0	0	1724	A		1	2	E	
Texas Western College	0	0	0	664	N	Y	U	U	U	
U. of Texas	0	2	7	2378	A		0	1	E	Two-week course
U. of Toledo	0	1	3	1053	S		3	3	E	ME, EE
U. of Toronto	0	1	0		S		3	4	P	IE, EE
Trinity College	0	0	0	56	*					
Tulane U.	0	0	0	293	N	Y	U	U	U	
Tufts U.	0	0	1	549	N	Y	U	U	U	
U. of Tulsa	0	0	0	599	A		3	2	E	
Union College and U.	0	0	0	415	N	Y	U	U	E	EE
U.S. Naval Postgraduate School	0	0	0	256	S		4	2	M	AE, EE, ME, Meteorology
Utah State U.	0	0	0	588	A		2	1	C	
U. of Utah	0	1	0	1149	N	Y	U	U	U	
Valparaiso U.	0	0	0	391	A		2	3	E	
Vanderbilt U.	0	0	1	660	N	N	3	3	M	Elective
U. of Vermont	0	0	0	327	*					
Villanova U.	0	0	0	1224	N	Y	U	U	C	
Virginia Military Inst.	0	0	0	417	N	Y	U	U	U	
Virginia Polytechnic Inst.	0	0	0	3332	S		5	4	E	All Depts.
U. of Virginia	0	0	0	684	S		3	1	E	ME
Washington U.	0	0	0	699	A		3	2	C	
Washington State U.	0	0	0	1091	N	Y	2	1	E	
U. of Washington	0	0	0	2208	N	Y	U	U	C	
Wayne State U.	0	4	2	1303	A		2	2	E	
Webb Inst. of Naval Architecture	0	0	0	74	*					
West Virginia U.	0	1	0	1147	S		3	2	E	IE, ME
U. of Wichita	0	0	0	824	N	N	1	2	E	Elective
U. of Wisconsin	1	1	2	3512	A		0	1	C	Four lecture hours
Worcester Polytechnic Inst.	0	0	1	974	N	Y	U	U	U	
U. of Wyoming	0	0	0	791	N	Y	1	4	E	
Yale U.	0	1	0	326	A		3	1	C	
Youngstown U.	0	0	0	1228	*					
	57	72	100							

Key: Column 6

N - No
A - Yes, in all programs
S - Yes, in some programs
* - No reply

Column 7

Y - Study in progress
N - No study in progress

Column 10

M - Mathematics
C - Computing Center
E - Engineering
U - Unspecified

V. COMPUTING CENTER SERVICES AT THE UNIVERSITY OF MICHIGAN

A Brief History of Computing Activities at The University of Michigan

There was a considerable digital computer design and construction effort at the University during the early 1950's (e.g., the MIDAC computer). Several engineering departments had purchased analog computers. However, no general-purpose, high-speed computer was available to the University community as a whole. This need was satisfied in 1955 with the rental of an IBM 650. The machine was installed under the jurisdiction of the already existing Statistical Research Laboratory directed by Prof. Cecil Craig of the University's Mathematics Department.

At first the new machine was operated on a completely open-shop basis, but within a few months the problem load had grown so significantly that a day-time staff of machine operators was required to eliminate processing bottlenecks. Programming was still kept on an open-shop basis, but "button pushing" by the individual user was no longer necessary (or permitted during a normal working day).

In the years from 1955-1959, demands for computer time grew steadily, until around-the-clock operation was inadequate to meet the needs of the machine's users. Some work was processed on the IBM 704 at The General Motors Corporation Technical Center, but by 1959 it was apparent that a much larger machine was required on campus.

The bulk of machine time during these years was used in four ways: 1) graduate thesis research, 2) sponsored research work, generated through projects of the University's then Engineering Research Institute, 3) automatic programming research, initiated by the staff of the computing facility, and 4) formal student instruction via a graduate-level computer course currently listed as Math. 473. The computer course taught in the Mathematics Department by Prof. John W. Carr III and Bernard A. Galler, regularly trained 80-120 students per semester. In later years, computer work was also occasionally assigned on an optional basis in some engineering graduate courses. Unless he was taking a graduate course for advanced credit, the undergraduate student in general had no access to the digital machine.

In response to the need for a larger machine, the IBM 650 was replaced in the late summer of 1959 by an IBM 704 with a complete complement of peripheral equipment for card and paper handling. The machine was installed in new quarters, the University Computing Center. The Center was organized as an independent entity within the University administrative structure. R. C. F. Bartels was appointed Director of the Center, with responsibility for overall policy residing in a University Computer Committee composed of representatives of the several colleges of the University. Administratively, the Director of the Center is responsible to Vice President for Research and Dean of the Rackham Graduate School, Ralph A. Sawyer.

About this same time a group of engineering faculty, feeling that the time had come for integration of computer use at the undergraduate level, began laying the groundwork for the Ford Project's activities with advice, encouragement, and active participation of Center personnel.

Faculty training by the Project began in the spring semester of 1960 as described in a previous section. At the same time, Math. 373, the sophomore level computer course (Introduction to Digital Computing), which has been described, was organized with about 200 students enrolled, most from the Engineering College. Some computer work was assigned to undergraduates in engineering courses during the semester, but not very much because of the lack of both trained faculty and computer-oriented students.

Beginning in the fall of 1960, Math. 373 became a required course for most engineering curricula with an enrollment of 350-550 students per semester. With the growing group of computer trained students and faculty, considerable computer activity in the undergraduate engineering classroom began. Much of this activity was generated by Project trained faculty although a substantial amount was also initiated by faculty who received their training elsewhere, primarily through self-teaching and research experiences or previous attendance at the graduate level computer course.

The amount of required engineering classroom computer work increased rather rapidly with each passing semester until the spring of 1961 when some 60-70 engineering classes used the computer. Since then approximately 65 engineering classes have been involved each semester.

In the fall of 1961, the IBM 704 was replaced by a somewhat faster machine, the IBM 709; this machine was in turn replaced by the significantly faster IBM 7090 in September of 1962. An IBM 1401 computer is being used for off-line card, paper, and magnetic tape handling.

The Center staff is composed of several full time administrative and research personnel, about a dozen graduate student assistants, and several machine operators. A primary research effort has been the development of the MAD (Michigan Algorithm Decoder) language and its implementation on the IBM 704, 709, and 7090 machines. A FAP-like assembly program with macro capabilities, called UMAP, has been written for both the 709 and 7090 machines. A very efficient and easy-to-use processing system called the University of Michigan Executive System has also been programmed for the three machines. In addition, the staff maintains an up-to-date library for all users. Most of this research effort has been documented and is available to others through the SHARE organization (users' organization for IBM 700/7000 series machines).

The staff, and in particular the graduate student assistants, are available for consultation to all University personnel and students. These assistants normally provide no programming services; they serve as last resort debugging experts and are available for answering questions concerning operating procedures, programming, etc.

In addition to serving students taking the graduate level computer course, Math. 473, the undergraduate computer course, Math. 373, and Engineering College classes, the Center provides computer time to several other groups of users. These include faculty and graduate students doing research work, students taking classroom work in the Business and Arts Schools, and the staffs of sponsored research projects (many government sponsored) being operated under University control. No University administrative or outside contract work is done on the machine. Only research or educational work is permitted.

Statistics of Computing Center Operation - Spring Semester, 1962

In an effort to indicate the kind and distribution of computer use during a typical semester, L. B. Evans of the Project staff wrote a comprehensive program to process some 26,000 time cards (produced automatically by the executive system, one for each "job" or problem submission) from individual machine runs during the spring semester 1962 (February 12 - June 16). Tables X and XI summarize by month the number of machine runs and amount of machine time used, classified according to processing function and user group. The processing functions are:

1. MAD compilation
2. FORTRAN compilation
3. UMAP (Symbolic Machine Language) assembly
4. Execution
5. Total

All times are for processing on the IBM 709 computer under control of the Michigan Executive System and do not include off-line card, tape, and paper handling done on an associated IBM 1401. Here <u>total</u> time refers to the total of any compilation,assembly and/or execution time and of time required by the executive system to call translators, search the library tape, load programs, and do the accounting. The eight user group classifications are:

1. Math. 373 (undergraduate computer course)
Math. 473 (graduate computer course)
Bus. Ad. (Business Administration computer course)
2. Engineering classes
3. All other classroom work in University
4. Graduate thesis research
5. Faculty research
6. Computing Center staff use
7. Sponsored research
8. All other

Table X also includes a percentage of runs submitted which were executed, a rough measure of compilation success. Tables X and XI show that the total machine load peaks rather sharply in

May, primarily because of high computer classroom use late in the semester. Of some 26,051 problems submitted, 13,016 or approximately half were generated by classroom assignments, with 5,778 from engineering class work. Less than 20% of all machine time was used for all these classroom problems, however.

Table XII shows a semester summary of Tables X and XI, while Table XIII shows average times (in seconds) per program run. Note that for all engineering problems, average run time was slightly over one minute (71.4 seconds). The typical MAD compile time of 26 seconds per program illustrates the high speed attained by the translator. This high compilation speed is primarily responsible for the ability to process the very large number of problems submitted during the semester. Typically, as shown in Table XIII, FORTRAN compilations for similar programs require 4-6 times the MAD compile times.

Table XIV is a breakdown of engineering classroom assignments run on the computer during the busiest one-month period (April 27 - May 26) showing the amount of activity generated by courses in each engineering department.

Table XV summarizes the data for all classroom use during the semester according to the following user groups:

1. Engineering classes
2. Math. 373 (undergraduate computer course)
3. Math. 473 (graduate computer course)
4. Bus. Ad. (Business Administration)
5. Others (Arts School)

Table XVI shows the frequency distribution of total problem running times for these user groups. The frequency distribution for engineering classes, Math. 373, and Math. 473 are shown in Figures Ia, Ib, and Ic respectively.

Table XVII summarizes percentages of machine time used by the user groups for the various processing functions.

It is obvious from these figures that engineering personnel are responsible for a very large fraction of total computer use at the University, i.e., a good part of Math. 373, Math. 473, faculty research, graduate research and sponsored research time must also be credited to engineering use. While these tables contain a rather formidable amount of information, the Project staff felt that all should be included to indicate the kind and extent of computer activity which can be expected at a sizable university with an active computing effort in both the research and educational areas.

TABLE X

University of Michigan Computing Center Statistics - Spring Semester 1962
Number of Individual Problems Submitted
Arranged by Month According to User Group and Processing Function

Total Number of Runs Submitted

Date	Engineering Classroom Assignments	Math 373,473 Bus. Ad.	All Other Classroom Work	Graduate Thesis Research	Faculty Research	Computing Center Staff	Sponsored Research	Other	Total
Feb. 12-28	72	65	18	452	331	449	741	30	2158
Mar. 1-31	833	1813	53	1031	554	414	1358	23	6079
Apr. 1-30	1322	1617	46	896	426	412	1322	13	6054
May 1-31	3270	3333	91	1118	515	427	1123	4	9881
June 1-16	281	199	3	479	277	110	528	2	1879
Total (Feb. 12 -June 16)	5778	7027	211	3976	2103	1812	5072	72	26051

Number of Runs Executed

Date	Engineering Classroom Assignments	Math 373,473 Bus. Ad.	All Other Classroom Work	Graduate Thesis Research	Faculty Research	Computing Center Staff	Sponsored Research	Other	Total
Feb. 12-28	55	37	15	403	299	336	619	19	1783
Mar. 1-31	568	1250	49	913	472	342	1211	20	4825
Apr. 1-30	858	1088	43	786	374	328	1161	8	4646
May 1-31	2231	2126	86	994	458	351	993	4	7243
June 1-16	233	161	3	418	238	94	478	2	1627
Total (Feb. 12 -June 16)	3945	4662	196	3514	1841	1451	4462	63	20124

Percent of Runs Submitted Which Were Executed

Date	Engineering Classroom Assignments	Math 373,473 Bus. Ad.	All Other Classroom Work	Graduate Thesis Research	Faculty Research	Computing Center Staff	Sponsored Research	Other	Total
Feb. 12-28	76.4	56.9	83.3	89.2	90.3	74.8	83.5	63.3	82.6
Mar. 1-31	68.2	68.9	92.5	88.6	85.2	82.6	89.2	87.0	79.4
Apr. 1-30	64.9	67.3	93.5	87.7	87.8	79.6	87.8	61.5	76.7
May 1-31	68.2	63.8	94.5	88.9	88.9	82.2	88.4	100.0	73.3
June 1-16	82.9	80.9	100.0	87.3	85.9	85.5	90.5	100.0	86.6
Average (Feb. 12 -June 16)	68.3	66.3	92.9	88.4	87.5	80.1	88.0	73.6	77.2

Number of Runs Involving MAD Compilation

Date	Engineering Classroom Assignments	Math 373,473 Bus. Ad.	All Other Classroom Work	Graduate Thesis Research	Faculty Research	Computing Center Staff	Sponsored Research	Other	Total
Feb. 12-28	61	14	10	205	148	115	322	18	893
Mar. 1-31	775	971	15	508	250	146	651	23	3339
Apr. 1-30	1287	1552	11	422	180	203	588	13	4256
May 1-31	3146	3070	36	418	212	218	531	4	7635
June 1-16	225	169	0	183	120	66	228	2	993
Total (Feb. 12 -June 16)	5494	5776	72	1736	910	748	2320	60	17116

Number of Runs Involving FORTRAN Compilation

Date	Engineering Classroom Assignments	Math 373,473 Bus. Ad.	All Other Classroom Work	Graduate Thesis Research	Faculty Research	Computing Center Staff	Sponsored Research	Other	Total
Feb. 12-28	5	0	5	36	27	32	45	6	156
Mar. 1-31	6	0	6	79	54	34	106	0	285
Apr. 1-30	4	0	5	63	26	34	112	0	244
May 1-31	8	1	3	97	30	28	87	0	254
June 1-16	3	0	2	16	22	6	47	0	96
Total (Feb. 12 -June 16)	26	1	21	291	159	134	397	6	1035

Number of Runs Involving UMAP Assembly

Date	Engineering Classroom Assignments	Math 373,473 Bus. Ad.	All Other Classroom Work	Graduate Thesis Research	Faculty Research	Computing Center Staff	Sponsored Research	Other	Total
Feb. 12-28	0	51	1	25	49	217	113	3	459
Mar. 1-31	8	889	0	52	55	212	149	0	1365
Apr. 1-30	8	61	3	36	31	332	179	0	650
May 1-31	19	219	0	71	34	134	112	0	589
June 1-16	2	21	0	63	15	41	95	0	237
Total (Feb. 12 -June 16)	37	1341	4	247	184	936	648	3	3300

TABLE XI

University of Michigan Computing Center Statistics - Spring Semester 1962
Machine Time* Requirements Arranged by Month According to User Group and Processing Function

	Engineering Classroom Assignments	Math 373,473 Bus.Ad.	All Other Classroom Work	Graduate Thesis Research	Faculty Research	Computing Center Staff	Sponsored Research	Other	Total
Total Machine Time Used in Minutes									
Feb. 12-28	106.86	38.04	86.70	1498.74	1183.02	2481.84	2657.58	96.48	8149.26
Mar. 1-31	868.99	1194.17	162.03	4148.38	2054.05	2661.73	5268.61	20.64	16378.60
Apr. 1-30	1260.81	1204.42	149.03	4289.17	1816.96	1423.71	4765.69	10.46	14920.25
May 1-31	4035.84	3334.44	228.72	6376.43	2634.61	1593.71	3246.39	2.82	21452.96
June 1-16	602.33	227.53	11.08	3705.62	1148.11	552.52	1711.24	2.93	7961.36
Total (Feb. 12 -June 16)	6874.83	5998.60	637.56	20018.34	8836.75	8713.51	17649.51	133.33	68862.43
Total Execution Time Used in Minutes									
Feb. 12-28	63.30	19.26	27.78	1179.36	987.42	1609.02	2459.36	75.54	6421.04
Mar. 1-31	536.76	578.12	135.85	3430.31	1661.55	2083.31	4372.59	11.47	12809.96
Apr. 1-30	742.86	512.47	112.20	3686.56	1573.18	643.78	3928.85	4.42	11204.32
May 1-31	2639.32	1389.58	188.37	5511.34	2282.03	1000.08	2544.46	1.22	15556.40
June 1-16	431.49	136.17	4.40	3494.54	1013.31	396.61	1238.91	1.85	6717.28
Total (Feb. 12 -June 16)	4413.73	2635.60	468.60	17302.11	7517.49	5732.80	14544.17	94.50	52709.00
Total MAD Compilation Time Required in Minutes									
Feb. 12-28	36.00	3.06	4.08	191.52	106.38	83.34	215.34	6.36	646.08
Mar. 1-31	299.98	281.43	8.67	465.75	185.66	78.89	431.50	8.57	1760.45
Apr. 1-30	505.55	672.81	10.13	377.88	120.26	175.36	360.68	6.04	2228.71
May 1-31	1379.48	1864.07	37.20	373.56	190.44	134.97	367.26	1.60	4348.58
June 1-16	161.77	82.92	0.00	152.59	81.88	33.12	179.44	1.08	692.80
Total (Feb. 12 -June 16)	2382.78	2904.29	60.08	1561.30	684.62	505.68	1554.22	23.65	9676.62
Total FORTRAN Compilation Time Required in Minutes									
Feb. 12-28	5.58	0.00	53.94	116.88	68.22	182.61	94.44	14.10	535.77
Mar. 1-31	14.18	0.00	17.09	222.52	168.84	100.11	326.65	0.00	849.39
Apr. 1-30	10.91	0.00	26.38	209.00	110.18	142.09	320.09	0.00	818.65
May 1-31	12.56	0.96	2.52	441.84	138.14	161.65	360.57	0.00	1118.24
June 1-16	8.50	0.00	6.68	34.94	43.62	15.91	222.85	0.00	332.50
Total (Feb. 12 -June 16)	51.73	0.96	106.61	1025.18	529.00	602.37	1324.60	14.10	3654.55
Total UMAP Assembly Time Required in Minutes									
Feb. 12-28	0.00	13.92	0.36	3.62	15.48	597.24	75.96	0.00	706.58
Mar. 1-31	1.33	289.98	0.00	17.26	31.22	464.32	119.79	0.00	923.90
Apr. 1-30	1.49	19.14	0.41	15.73	13.34	517.67	156.07	0.00	723.85
May 1-31	4.48	79.83	0.00	49.69	23.94	297.01	79.04	0.00	533.99
June 1-16	0.57	8.47	0.00	23.55	9.30	106.88	70.04	0.00	218.81
Total (Feb. 12 -June 16)	7.87	411.34	0.77	109.85	93.28	1983.12	500.90	0.00	3107.13

* All times listed here are for processing on the IBM 709 computer under control of The University of Michigan Executive System. An IBM 1401 computer is used for all card and paper handling off-line.

TABLE XII

Overall Semester Summary
Number of Problems Submitted and Machine Time Requirements
Arranged According to User Group and Processing Function
The University of Michigan Computing Center Statistics - Spring Semester 1962
(All Times in Minutes)

	Engineering Classroom Assignments	Math 373,473 Bus.Ad.	All Other Classroom Work	Graduate Thesis Research	Faculty Research	Computing Center Staff	Sponsored Research	Other	Total
Number Submitted	5778	7027	211	3976	2103	1812	5072	72	26051
Number Executed	3945	4662	196	3514	1841	1451	4462	53	20124
No. of MAD Compilations	5494	5776	72	1736	910	748	2320	60	17116
No. of FORTRAN Compilations	26	1	21	291	159	134	397	6	1035
No. of UMAP Assemblies	37	1341	4	247	184	936	648	3	3400
Total Time	6874.83	5998.60	637.56	20018.34	8836.75	8713.51	17649.51	133.33	68862.43
Execute Time	4413.73	2635.60	468.60	17302.11	7517.49	5732.80	14544.17	94.50	52709.00
MAD Time	2382.78	2904.29	60.08	1561.30	684.62	505.68	1554.22	23.65	9676.62
UMAP Time	7.87	411.34	.77	109.85	93.28	1983.12	500.90	0.00	3107.13
FORTRAN Time	51.73	.96	106.61	1025.18	529.00	602.37	1324.60	14.10	3654.55

TABLE XIII

Overall Semester Summary
Average Machine Time Requirements Per Problem in Seconds
Arranged According to User Group and Processing Function

	Engineering Classroom Assignments	Math 373,473 Bus.Ad.	All Other Classroom Work	Graduate Thesis Research	Faculty Research	Computing Center Staff	Sponsored Research	Other	Average
Total Time	71.4	51.2	181.3	302.1	252.1	288.5	208.8	111.1	158.6
Execute	67.1	33.9	143.4	295.4	245.0	237.1	195.6	107.0	157.2
MAD	26.0	30.2	50.1	54.0	45.1	40.6	40.2	23.7	33.9
UMAP	12.8	18.4	11.6	26.7	30.4	127.1	46.4	0.0	54.8
FORTRAN	119.4	57.6	304.6	211.4	199.6	269.7	200.2	141.0	211.9

TABLE XIV

Machine Load for University of Michigan Engineering Classroom Assignments Only
Arranged by Engineering Discipline for the Period April 27, 1962 - May 26, 1962

Department	No. of Active Classes	Compile Time (min.)	Execution Time* (min.)	Total Machine Time (min.)	No. of Runs	Averages: Compile Time (sec.)	Averages: Execute Time (sec.)	Averages: Total Time (sec.)	Percentages: Compile Time	Percentages: Execute Time
Civil	14	349.35	590.42	939.77	870	24.1	40.7	64.8	37.2	62.8
Chem.-Met.	15	193.58	407.77	601.35	468	24.7	52.1	76.8	32.2	67.8
Electrical	11	183.41	327.94	511.35	493	22.4	40.0	62.4	35.8	64.1
Engr. Mech.	1	4.64	16.10	20.74	15	18.5	64.3	82.8	22.4	77.6
Engr. Science	1	12.32	25.63	37.95	38	19.5	40.5	60.0	32.5	67.5
Industrial	7	103.99	131.01	235.00	267	23.4	29.4	52.8	44.3	55.7
Mechanical	11	140.26	350.30	490.56	483	17.5	43.7	61.2	28.6	71.4
Naval Arch.	1	74.81	134.41	209.22	203	22.1	39.7	61.8	35.8	64.2
Totals	61	1062.36 (17.71 hours)	1983.58 (33.06 hours)	3045.94 (50.77 hours)	2837	22.5	41.9	64.4	34.9	65.1

* Includes processing time, i.e., time required by executive system to call translators, search library, load programs, and do accounting.

TABLE XV

Summary Data on All Classroom Computer Use at The University of Michigan
Spring Semester, 1962

	Engr.	Math.373	Math.473	Bus.Ad.	Others	Total or Average
Number Submitted	5778	3249	2674	1104	211	13016
Number Executed	3945	2176	1668	818	196	8803
Number MAD Compilations	5494	3244	1882	650	72	11342
Number FORTRAN Compilations	26	0	1	0	21	48
Number UMAP Assemblies	37	0	918	423	4	1382
Total Machine Time (min.)	6874.8	2053.0	2736.5	1208.8	637.6	13510.7(225.2 hr)
Execution Time (min.)	4413.7	1026.7	872.7	735.1	468.6	7516.8(125.0 hr)
MAD Compile Time (min.)	2382.8	1031.3	1467.1	405.8	60.1	5347.1 (89.1 hr)
FORTRAN Compile Time (min.)	51.7	0.0	1.0	0.0	106.6	159.3 (2.7 hr)
UMAP Assembly Time (min.)	7.9	0.0	288.7	122.5	8.8	419.9 (7.0 hr)
Average Total Time (sec.)	71.4	37.9	61.4	65.7	181.3	62.3
Average Execution Time (sec.)	67.1	28.3	31.4	53.9	143.4	51.3
Average MAD Compile Time (sec.)	26.0	19.1	46.8	37.5	50.1	28.3
Average FORTRAN Compile Time (sec.)	119.3	0.0	60.0	0.0	304.8	199.0
Average UMAP Assembly Time (sec.)	12.8	0.0	18.9	17.4	11.6	18.2
Percent Runs Executed/Runs Submitted	68.2	67.0	62.4	74.1	92.9	67.6
Percent Translation Time/Total Time	35.5	50.2	64.2	43.7	26.1	43.8
Number of Students		{215 pairs / 430 stud.}	95			
Average Time/Student (min.)		9.54 (per pair)	38.82			
Number of Assigned Problems		4	5			
Average Number of Runs/Student		15.1 (per pair)	28.2			
Average Number of Runs/Problem		3.8	5.7			

TABLE XVI

Tabulated Total Machine Time Frequency Distribution for Mathematics, Engineering, and Business Classroom Use

Number of Machine Runs (Time in Seconds)

Courses	0 25	25 50	50 75	75 100	100 125	125 150	150 175	175 200	200 250	250 300	300 400	400 500	500 750	750 1500	1500 3000	300 600
Bus. Ad.	61	212	328	223	96	38	29	20	19	17	32	17	16	11	0	
Math. 373	374	1076	868	805	116	30	15	11	17	6	11	3	5	1	0	
Math. 473	98	725	681	551	175	93	68	37	68	64	70	26	28	14	1	
All Engr. Classes	432	1462	1450	818	456	267	175	138	168	104	157	73	114	67	11	

Frequency Distribution

Courses	0 25	25 50	50 75	75 100	100 125	125 150	150 175	175 200	200 250	250 300	300 400	400 500	500 750	750 1500	1500 3000	300 600
Bus. Ad.	.0545	.1895	.2931	.1993	.0856	.03396	.02592	.01787	.01698	.01519	.02860	.01519	.01430	.00983	0	0
Math.373	.11204	.32235	.26004	.24116	.03475	.00899	.00449	.00330	.00509	.00180	.00330	.00090	.00150	.00030	0	0
Math.473	.03631	.26862	.25232	.20415	.06484	.03446	.02519	.01371	.02519	.02371	.02594	.00963	.01037	.00518	.00037	0
All Engr. Classes	.07336	.24826	.24622	.13890	.07743	.04534	.02972	.02343	.02853	.01766	.02666	.01240	.01936	.00968	.00187	.0011

Courses	Mean (seconds)	Standard Deviation (seconds)
Bus. Ad.	65.7	25.25
Math. 373	37.9	14.33
Math. 473	61.4	17.80
All Engr. Classes	71.4	20.50

TABLE XVII

Overall Semester Summary
University of Michigan Computing Center Statistics - Spring Semester 1962
Percent Allocation of Machine Time by User Group

	Total	Execution	MAD Compile	FORTRAN Compile	UMAP Assembly	% of Problems Submitted
Engineering Class Use	9.98	8.37	24.62	1.42	0.25	22.18
Math. 373	2.98	1.95	10.67	0.00	0.00	12.47
Math. 473	3.97	1.66	15.17	0.03	9.29	10.26
Bus. Ad. Class Use	1.76	1.39	4.19	0.00	3.94	4.23
Other Class Use	0.93	0.89	0.62	2.92	0.02	0.81
All Classroom Use	19.62	14.26	55.27	4.37	13.50	49.95
Graduate Thesis Research	29.07	32.82	16.13	28.05	3.54	15.26
Faculty Research	12.83	14.26	7.07	14.48	3.00	8.07
Comp. Center Staff Use	12.65	10.88	5.23	16.48	63.83	6.96
Sponsored Research	25.63	27.59	16.06	36.24	16.13	19.47
Other	0.20	0.19	0.24	0.38	0.00	0.29
	100.00	100.00	100.00	100.00	100.00	100.00

FIGURE Ia
Machine Time Frequency Distribution for Engineering Classroom Assignments
Spring Semester 1962

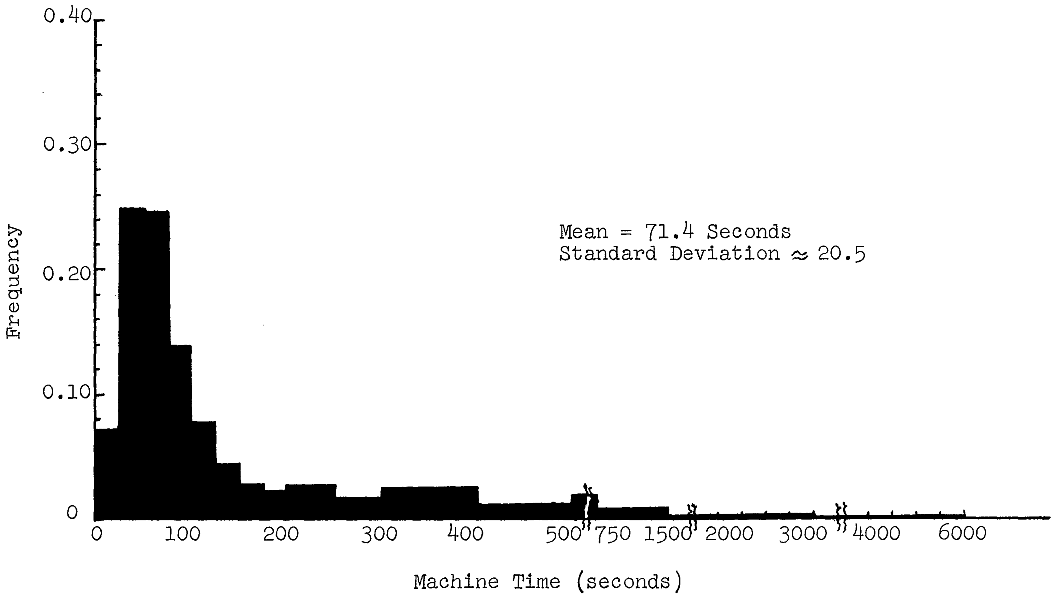


FIGURE Ib
Machine Time Frequency Distribution for Introductory Computer Course
(Math. 373) Assignments - Spring Semester 1962

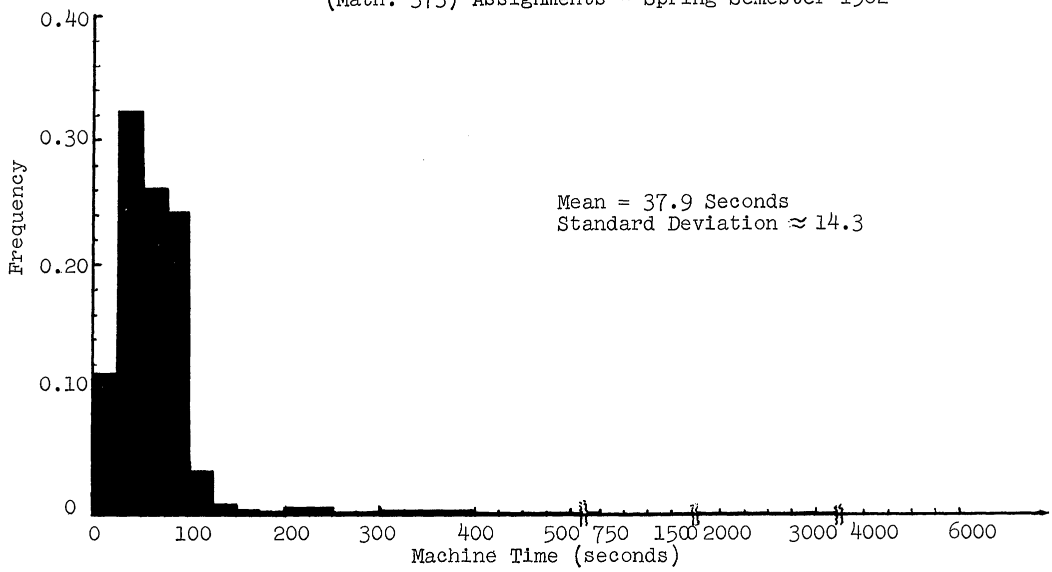
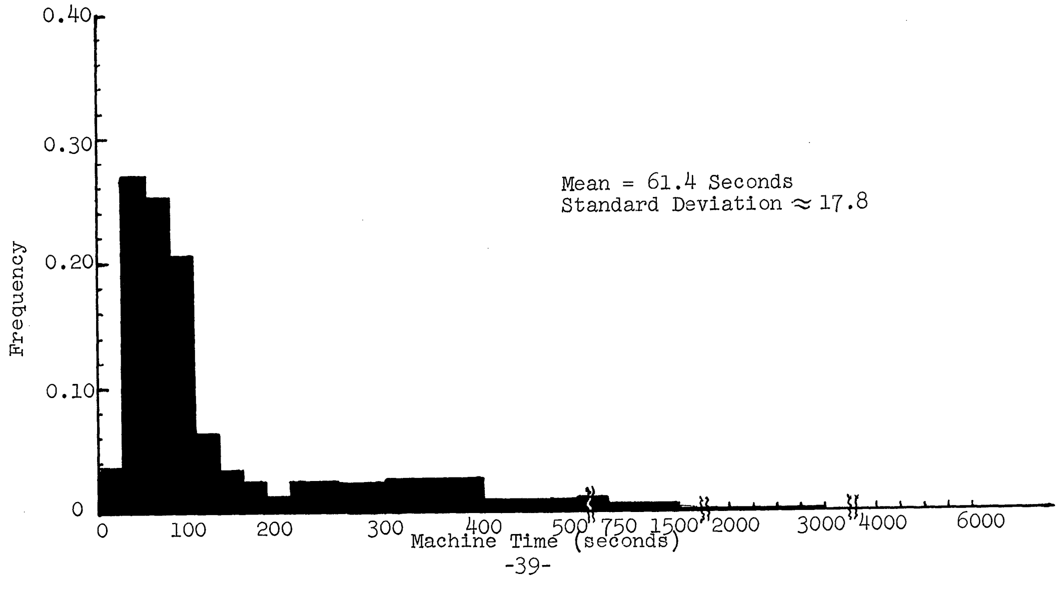


FIGURE Ic
Machine Time Frequency Distribution for Advanced Level Computer Course
(Math. 473) Assignments - Spring Semester 1962



VI. SOME FACTORS AFFECTING EDUCATIONAL USE OF COMPUTERS

Language and Hardware Development

A necessary prerequisite for incorporation of practical large-scale computer usage into the engineering educational process was the development of general, simple-to-learn procedure-oriented languages. FORTRAN, one of the first such procedural languages, became available for some IBM machines in 1956. However, as late as mid-1960 there was still argument about the advisability of utilizing the procedure-oriented languages for student work, and even today some educators believe that knowledge of machine level languages must be required of the computer user. There is little doubt, however, that the trend toward procedure-oriented languages is accelerating, not only among casual computer users, but among professional programmers (particularly in the scientific areas) as well.

The procedure-oriented languages now available on most machines require a minimum level of attention to programming details, permitting the bulk of the programmer's efforts to be focused on the problem-solving process, i.e., on problem structure. Part of the reluctance to accept procedure-oriented languages results from resistance by some experts in the field who, after many years of experience, find they can use machine languages very effectively. These people overlook the time and effort that is required to teach students or new people entering the field the knowledge they have acquired over a period of years. One measure of the difficulties which the machine-oriented languages present is found by an observation that persons working in the computer field in the period 1953-1956 today are often unaware of the advantages to be gained by introducing new and relatively inexperienced people to the computing field. Many times persons are found who struggled along with machine-oriented languages several years ago and who have little enthusiasm for employing computers today because of their recollections. Such people doubt the wisdom of having students program their problems for the computer.

Of necessity, problems which can be solved by beginning students writing in machine language are trivial compared with those which the same student can solve with a more general algebraic or algorithmic language. There seems little doubt that the Project would have been ill-timed had not adequate language development taken place in the late 1950's.

Accompanying the significant improvements in the languages used for communicating with computers, some spectacular improvements have been made in the computer equipment or "hardware" available to colleges and universities. In the period from 1960 to 1962, computers in every category, small, medium, and large scale, were being replaced by newer equipment of from 5 to 10 times the capability (speed, memory, input-output, and other factors combined). This upward trend in computer capacity per university dollar expended promises to continue. Plans for the future must include recognition of continued changes.

Estimates were given in Table IC in the First Annual Report on hardware requirements for a hypothetical engineering school. These estimates, based on 1960 hardware and software available at that time, are reviewed in a new table here and compared with estimated figures for 1962 equipment and software in Table XVIII.

The Important Role of the Computing Center

Each institution has its own history of development in the computing area and wide variations will be found from school to school. Some schools have a single computing facility for all business and scientific calculations. Others have computing centers for scientific calculations alone. Still others have multiple installations with individual departments or colleges within a university having separately administered computing facilities. It is not the purpose of this report to discuss in detail the many issues involved in the administration of the computing facilities within a university, but rather to make some general observations on principles which seem to be important when the goal is to assure effective and efficient instruction of engineering students in machine computation. Four particularly important requisites for really successful large-scale student use of computer facilities are as follows:

1. The machine must be made readily accessible to students and faculty. This does not at all imply that a machine should be operated on an "open shop" basis, i.e., that users should be allowed to push the buttons and operate the machine. It does mean that there should be a minimum amount of administrative red tape for requesting and getting approval to use the machine without charge. Although some controls are needed, the necessary procedures should be simple and well known. Perhaps the best arrangement for submitting programs is to have some "mailbox" or "window" arrangement where the student can deposit his program for running, and later pick it up after processing on the computer. Although progress has been made in this connection generally, questionnaires from Project participants indicate that access to the machine for educational purposes is still a problem at many schools.

2. Programming should be on an essentially "open shop" basis, i.e., machine users should write their own programs, preferably in a good procedure-oriented language (ALGOL, FORTRAN, MAD, etc.). The center staff should provide necessary library subroutines to implement the common numerical methods and function computations (sine, square root, simultaneous equation programs, etc.). The procedure-oriented language chosen should, if possible, have built-in provision for the writing of other subroutines (external functions). Machine-oriented language programming aspects (such as card and printer format information) should be minimized or at least simplified as much as possible. It should be remembered that the average computer user is (and should be) much more interested in the procedure for solving his problem than in specific details of how his card images are written on magnetic tape, or how the printer operates, etc.

TABLE XVIII

Projected Estimates of Computer Use for Instruction in a
Hypothetical Engineering College of 2400 Students
(Using typical hardware and software)

Hardware / Software			IBM 704 MAD, U-M System		IBM 7090 MAD, U-M System		IBM Basic 650 FORTRANSIT FLATRAN, etc.		Expanded IBM 1620* FORTRAN LOAD & GO	
			Computer Time							
Year	No. of Students	Assign-ment No.	Min.**	Hours Per Day+	Min.**	Hours Per Day+	Min.**	Hours Per Day+	Min.**	Hours Per Da
Freshman	700	-	-		-		-		-	
Sophomore	500	1	3.0		.8		45.0 ++		4.9	
		2	2.0	.42	.6	.11	36.0 ++	6.30	3.9	.84
		3	4.5		1.0		63.0 ++		6.8	
Junior	450	4	3.0		.6		45.0++		5.0	
		5	5.1	.61	1.0	.12	45.0	6.60	10.0	1.28
		6	7.5		1.5		80.0		18.0	
Senior	350	7	9.0	.82	2.0	.15	90.0	9.50	20.0	2.26
		8	18.0		3.0		225.0		55.0	
Ist Grad.	400	9	36.0	2.50	6.0	.42	240.0	33.40	60.0	9.05
		10	36.0		6.0		720.0		200.0	
Grand Total - Hours Per Day				4.35		.87		55.80		13.43

* 40,000 to 60,000 character memory and some additional features such as high speed card input-output using load and go approach and punching out only results or diagnostics.

** Total time per problem assignment per student including repeat runs to correct errors.

+ Based on 6 day per week operation over a 32 week year.

++ Revised upward from figures given in First Annual Report.

3. The facility should be so organized that large numbers of small problems can be handled expeditiously. Rapid turn-around time (the elapsed time between program submission and its return from the computer) is of prime importance in instruction, and delays of more than one or two days interfere rather drastically with the educational process. This implies "closed shop" operation of computing facilities in most instances. For nearly all machines and in every case for large ones, it is essential to have available a fast, efficient executive or processing system with batch-processing abilities (i.e., the ability to run a large number of individual small problems in sequence without manual intervention by a human operator).

4. Individual course or department budgets should probably not be charged directly for educational use of the machine. Such emphasis on costs tends to limit machine use on the basis "we can't afford it." It seems more reasonable to operate a computer facility much as the university operates its libraries, i.e., if the installation is contributing to the educational process, it should be considered as an educational service chargeable to general college operating funds with a budget appropriate for the services rendered.

The personnel associated with the computing facility should provide technical assistance (this does not imply the writing of programs, but rather the giving of advice) to faculty and students. Since center personnel often will be involved in the educational program, they should be expected to provide leadership in introducing new methods and concepts evolving from the computer technology.

While some machines are equipped to use punched paper tape readers or typewriters as the primary input devices, the punched card is currently by far the most prevalent and useful form for preparation of student problems. Some advantages of cards are cost (quite low), the ease of program editing and modification, the ability to prepare the source language program off-line using relatively inexpensive keypunches (i.e., not tying up the computer), and the permanence of the program in punched card form. At The University of Michigan several keypunches have been installed throughout the Engineering College as well as in the Computing Center. Students must punch their own programs. It must be admitted that there is little educational merit in student keypunching, but the cost of providing keypunch service may be prohibitively high when thousands of persons are using the Computing Center facilities each semester. Some schools do provide keypunching service for machine users. If a cost analysis were made, it might well be shown that the hiring of skilled keypunch operators to punch all programs would actually be less expensive than current practice. This would result from machine time saved (fewer keypunching errors in programs), and the smaller number of keypunches required. It seems possible that eventually secretaries in college or departmental offices might be trained to keypunch.

Computer Size

University administrators often have to make decisions about computer size. (Is one large computer better than several small ones?, etc.) Experience tends to support the view that a university should have at least one large computer. This enables students and faculty to have a more powerful and, from a dollars-per-computation standpoint, less expensive machine to solve large and complex problems generated in classroom or research work. In addition, one large machine can serve as the focal point for a unified staff effort to provide better computing services for everyone on a university-wide basis. This also implies that, since the same equipment and language are available to all, there should be enhanced interdepartmental communication. Students using the computer in a course in one department would not need to learn a new language or new procedures when assigned a problem in another department.

Thus if a choice has to be made between several small machines and one large machine, this large machine should be given priority. However, a small machine does have some advantages for special purposes; e.g., for essentially real-time applications where man-machine communication is needed during the running of the program. An example of such a machine in engineering education might be one programmed to simulate production or management decision processes, i.e., where the computer functions as the laboratory for some Industrial Engineering course. (See Appendix A, The Use of Computers in Industrial Engineering Education*)

In many cases, small computers are chosen because the purchaser thinks in terms of immediate machine accessibility as compared with a turn-around-time of a day or perhaps, at best, a few hours for a closed-shop large-machine center. It is apparent, however, that when the loads increase for instructional purposes, the turn-around time on small machines increases too. Then, for an equivalent total number of users and an equivalent investment, the queues become even larger on small than large machines. This comes about because small machines in general are more expensive per computation, and the essential programs for efficient batch processing, load-and-go compiling, etc., are often unavailable for them.

Some schools desire a small machine because they believe that "button pushing" is a virtue. But most experienced computer people now agree that the student gains very little by operating the equipment himself. Unfortunately, newcomers to the field are often unwilling to accept the judgment of earlier workers that little or nothing about problem solving is learned by punching buttons. Generally the inexperienced student will waste large blocks of machine time which could be used by others. Skilled machine operators make much more efficient use of the equipment and permit the student to concentrate on the problem structure rather than on the superfluous details of machine operation.

Remote Use of Computers

One experience may be of interest to schools considering the use of a computer some distance away. While there has been some work on the development of remote consoles or typewriters which can communicate directly with the central processing unit of the computer, there are currently no such installations operating at universities (the MIT Computation Center has done some experimental work in this area).

At present a more mundane approach is being used with success at The University of Michigan and at the University of Houston (and undoubtedly elsewhere as well). In 1959 the Project set up two collection depots in different buildings of the Engineering College; students may deposit their decks of cards for later transportation to the Computing Center. Twice daily, messengers take the deposited program decks to the Center for processing and return with completed programs.

* Note: Appendix A is included only in the bound "library" copies of this report, but is available from the Project office as a separate curriculum report.

With card punches available in the engineering buildings, students and faculty may use the computer at the Center two blocks away without going near it. Thus, as far as the students are concerned, the Computing Center could be next door or miles distant as long as rapid transit takes place between the depot and the Computing Center.

This idea was later extended at the University of Houston which is using the IBM 709 computer at Texas A. and M. College, some 100 miles from Houston. The decks of cards are shipped by public bus transportation between Houston and College Station, employing student messengers at both ends of the line. Turn-around times of less than 24 hours are now being achieved consistently. The University of Michigan operating system is used on the Texas A. and M. computer, including the MAD language. There have been no mechanical difficulties in operating the system at Texas A. and M. With over 4000 jobs run during the past year, essentially all language and operating system problems brought in by faculty and students have been resolved adequately by the University of Houston Computing Center staff without communicating either with Ann Arbor or with Texas A. and M. This operation demonstrates the feasibility of one school using the facilities of a large computing center at another school (or industrial establishment) within normal communication distances, provided personnel at both sites are cooperative and properly informed. When economically justified, the next step in the process will likely be the use of teleprocessing stations at both ends of a leased telephone line to eliminate the physical movement of card decks and printed output over long distances. Turn-around-time should be reduced accordingly.

Costs of Processing Student Problems

Two years' experience have been built up in processing large numbers of engineering student problems at The University of Michigan (approximately 10,000 problem assignments, equivalent to 30,000 computer "jobs"). Records now permit fairly realistic cost estimates for operation with both small and large scale systems. Table XIX offers a guide to costs based on the experience at Michigan with supporting evidence furnished from experiences at the Universities of Houston, Kentucky, and Alberta in 1961-62.

This table was constructed by extracting time estimates from Table XX and by using average hourly rates for large and small scale computer systems. The hourly rates were obtained from the budget data given in a recent survey prepared by the University of Rochester.* For the

* Fifth Annual Survey of University Computing Centers, July 1961, University of Rochester Computing Center, Dr. T. A. Keenan, Director.

large scale system, the rates of the IBM 7070, 704, 7090, 709, CDC 1604, and UNIVAC 1105 computers were used and weight-averaged to yield an hourly cost of $191.00. For the small scale system, the IBM 1620, 650, LGP-30, and the Bendix G-15 were used to produce a cost figure of $37.00 per hour.

TABLE XIX

A Rough Guide to Current Computation Costs per Student for Engineering Classroom Problem Assignments* Using Large and Small Scale Computers**

Problem Level	Typical No. of Assignments	Large Scale Cost per Assignment	Total Cost	Small Scale Cost per Assignment	Total Cost	Unit Cost Rates Small/Large
Sophomore	3	$ 2.50	$ 7.50	$ 3.20	$ 9.60	1.3
Junior	3	3.29	9.87	6.78	20.34	1.9
Senior	2	7.94	15.88	23.10	46.20	2.9
1st Grad.	2	19.10	38.20	80.20	160.40	4.2
Total	10		$71.45		$236.54	3.3

* Includes cost of repeating computer runs to correct errors. An average of 3 computer runs per assignment is assumed.

** Assumes use of best available software (operating system and fast compiler).

It can be seen that small scale computers offer attractive unit costs, relative to large computers, primarily for elementary or beginner-level problems. Comprehensive senior-graduate level pre-thesis problems can be handled on the smaller computer only at substantial sacrifice in efficiency relative to the large computer.

Perhaps the most important information here is the clear message that the cost of processing student computer problems has now dropped to a level which is quite comparable with the laboratory fees of typical undergraduate chemistry courses.

VII. LITERATURE AND DISSEMINATION OF INFORMATION

Early in the Project it became clear that there was a dire shortage of literature for teaching beginning students the fundamentals of computing. Manuals on computers and computer languages were available, but they were written primarily for more expert computing center personnel. Accordingly, much Project effort was spent in preparing instructional material for both students and faculty. This effort took the form of texts and example problems to illustrate engineering computer applications suitable for classroom use. Text material was written by Project personnel, and in some cases by others at the University, and typed, published and distributed at Project expense. Partly to fulfill the need for illustrative problems and partly to serve as a training device, each faculty member who participated either for a summer or semester was asked to prepare one or more example problems suitable for publication and distribution to others. In addition, the Project staff felt that one of its primary obligations was the documentation of its activities in the form of periodic reports, and the distribution of these reports along with the teaching-text material and example problems to engineering educators throughout the United States, Canada, and other areas of the free world. Several papers were also prepared for presentation at technical meetings, and Project staff members were frequently asked to speak informally to engineering groups.

Within The University of Michigan, several special lectures, meetings and conferences were held to disseminate information and literature. These will be described in section VIII.

Project Reports

A series of seven Project reports was prepared as listed in Table XX. The first report included the following statement of Project objectives:

1. "The technical demonstration of the solution of computer-oriented problems suitable for illustrating principles in all branches of engineering.

2. "A review of methods for presenting scientific principles and their applications to students. This study should stimulate the existing faculties to incorporate the most modern material in their courses.

3. "The encouragement of all engineering schools to utilize computers more fully in engineering instruction, through faculty participation, conferences, and reports."

The first three reports listed in Table XX were given limited distribution to a dozen or so schools closely associated with the Project in the formative period. Starting with the First Annual Report in August of 1960, copies of all reports were distributed to deans of all engineering schools on the American accredited list. Other schools in Canada, the United States, and other free world countries which came to the attention of the Project through inquiries were also added to the list. The master list of engineering schools given in Table XXXIa was used for distribution of most Project literature.

Publication of this final report in three different forms needs a word of explanation. The first form is a composite of the final Project report prepared by the Project staff and the several curriculum reports on the use of computers in particular engineering programs prepared by faculty in those engineering subject areas. It is hard bound, 750 pages long and distributed to libraries at the listed engineering schools as well as to all Project participants. Paper back copies of the report without the individual curriculum studies are also being made available and distributed to deans and department heads at the listed engineering schools. Separate copies are available free of charge from the Project office for those interested. The individual curriculum studies in the use of computers in particular engineering subject areas are also being published as separate paper back reports. All are printed in sufficient numbers so that each member of the full-time faculty of the schools listed in Table XXXIa may have a copy of the report for his discipline. These are being issued simultaneously with the distribution of the combined hard bound copies. Additional copies of these reports are also available from the Project office on request.

TABLE XX

Project Reports

1. Initial Project Statement, Lithoprint, 11 pages, Oct. 21, 1959. Limited Distribution.

2. First Progress Report, Lithoprint, 8 pages, Feb. 16, 1960. Limited Distribution.

3. Second Progress Report, Lithoprint, 6 pages, June 23, 1960. Limited Distribution.

4. First Annual Report, Katz, D. L. and E. I. Organick. Lithoprint, 597 pages, Aug. 26, 1960.

   Copies Printed: 2500 (500 hard bound, 2000 paper back)
   Distributed to: Engineering deans, libraries, participants
   Availability: Limited copies in paper back edition available from Project office

5. Third Progress Report, Katz, D. L., Navarro, S. O., and B. Carnahan. Lithoprint, 29 pages, June 17, 1961.

   Copies Printed: 1300
   Distributed to: Engineering deans, participants
   Availability: Out of print

6. Second Annual Report, Katz, D. L., Organick, E. I., Navarro, S. O., and B. Carnahan. Lithoprint, 302 pages, Dec. 15, 1961.

   Copies Printed: 2000
   Distributed to: Engineering deans, computing center directors, participants
   Availability: Limited copies available from Project office

TABLE XX, Continued

7. Final Report, Katz, D. L., Organick, E. I., Navarro, S. O., and B. Carnahan. Lithoprint, 750 pages, Jan, 1963.

Copies Printed: 850 hard bound, complete report; 2000 paper bound, staff report only

Distributed to:

Hard bound copies to engineering school libraries and participants. The "staff" edition without curriculum reports to department chairmen of all engineering schools. The curriculum reports printed in paper cover as follows are being distributed to appropriate full time faculty members at all engineering schools.

Industrial Engineering	1400 copies
Mechanical Engineering	2500 copies
Civil Engineering	2400 copies
Electrical Engineering	2800 copies
Metallurgy and Materials Engr.	900 copies
Engineering Mechanics	400 copies
Naval Architecture	200 copies
Chemical Engineering	1200 copies
Aeronautical Engineering	700 copies

Availability:

A limited number of hard bound complete reports available to requesting libraries. Limited copies of curriculum reports and separate staff report (all paper bound) available from Project office.

Teaching Materials

The first effort in the preparation of teaching material was a set of notes called A Primer for Programming with the MAD Language written by E. I. Organick. These notes were published in the First Annual Report and also as a separate booklet, and served as the basis for a subsequent edition entitled, A Computer Primer for the MAD Language. One feature of the later editions of the Primer was to make it essentially a self-teaching text. A set of drill exercises was prepared at each stage in the development of the language to allow the student to test his own progress. Following his participation in the Project and his experience in preparing the MAD Primer, E. I. Organick proceeded on his own to prepare a similar FORTRAN Primer to be published by Addison-Wesley Publishing Company early in 1963.

A parallel effort to prepare instructional material for the analog computer was made in the form of notes written by R. M. Howe of the Department of Aeronautical and Astronautical Engineering. Here too, the need was for a simple presentation of the fundamentals. These notes were also included in the First Annual Report. S. O. Navarro amplified and rewrote his material in the analog field, and the Project published a booklet titled, Analog Computer Fundamentals, which he plans to incorporate into a book.

B. A. Galler, one of the authors of the MAD language, was in the process of preparing a manuscript entitled, The Language of Computers. Because the Computer Committee was interested in expediting the appearance of his book, the Project staff typed and proofread the copy and published a preliminary lithoprint edition distributed in 1961. The book has now appeared as a McGraw-Hill publication.

Students in Mathematics 373, the one-hour undergraduate computing course, needed a textbook to accompany the lectures given by B. W. Arden (another co-author of MAD). Accordingly, Mr. Arden prepared a text which the Project staff put into form for lithoprinting and published as a preliminary edition under the title, An Introduction to Digital Computing. This paper back edition had a limited distribution to the engineering school computing center directors through the Project and the Addison-Wesley Publishing Company. Mr. Arden has recently revised the book and it will appear as a hard cover Addison-Wesley publication early in 1963.

During the summer of 1962, a set of notes on numerical methods useful in solving engineering problems was prepared by Prof. H. A. Luther of Texas A. and M. College, James O. Wilkes, and Brice Carnahan, both of The University of Michigan. These notes were an outgrowth of the lectures on intermediate level topics in numerical analysis given during the summer faculty programs of 1960 and 1961 by R. C. F. Bartels and W. M. Kincaid. The new material should be available in a paper back edition early in 1963. Topics covered in the text include Interpolation, Integration, Solution of Non-linear Equations, Elementary Matrix Operations, Vectors, Eigenvalues and Eigenvectors, Systems of Linear and Non-linear Equations, Ordinary Differential Equations, Partial Differential Equations, and Statistics. The text will include some 50-60 completely flow-diagrammed and programmed illustrative programs written in the MAD language.

In the summer of 1962 the Project sponsored a study of the use of formal logic in solving engineering problems. During the first week of the study, approaches to developing improved methods of teaching problem solving techniques were discussed intensively. A group of twelve people participated in the discussions including Prof. Howard F. Rase from The University of Texas. During the remainder of the summer period, Prof. Irving M. Copi, Franklin H. Westervelt, and Robert G. Squires, with some assistance from B. Carnahan, S. O. Navarro, and D. L. Katz, prepared a report. The report, issued as an 89-page booklet presents the results of the study including a preliminary programmed text for four relatively simple engineering problems and a statement by Prof. Copi on the use of symbolic logic in solving engineering problems.

During the first two years of Project activity, a Royal McBee LGP-30 computer was available to students and faculty. R. N. Pease provided instructional and technical assistance to those using the computer. A manual for the ACT III language was prepared for local use, with some distribution outside the University as requested. For a period of one year a Bendix G-15 computer was also available to faculty and students. Instructional assistance was provided for those desiring to use the computer. A manual describing the BAD language was prepared by E. I. Organick and R. P. Crabtree for local instructional use.

During the summer of 1962, four professors were assisted in the preparation of instructional material related to advanced-level courses. Glen V. Berg of the Civil Engineering Department prepared a set of notes entitled, Computer Analysis of Structures. Paper back editions of these notes will be distributed by the Project during the spring of 1963. Kuei Chuang of the Electrical Engineering Department prepared a paper on the use of computers in teaching the design of optimal control systems. Walton M. Hancock worked on material on the use of computers in simulating production processes in conjunction with some graduate Industrial Engineering courses. Frederick G. Hammitt studied the use of computers in designing nuclear propelled rockets. Material prepared by these professors will probably be put on multilith masters for limited distribution to interested persons.

Occasionally an instructor or graduate student at the University prepared computer-related material of sufficiently general interest to justify printing and distribution by the Project. William D. Drake of the Industrial Engineering Department prepared a paper (presented at an American Institute of Industrial Engineers meeting in Atlantic City, May 1962) on a management decision game written for the LGP-30 computer and used by industrial engineering students. Robert F. Rosin, a graduate student in the Communication Sciences program, prepared a history of computing machines viewed from the standpoint of their organization. This survey includes a description of some of the very early machines designed by Charles Babbage in the 19th century, and the most important of the modern machines. Table XXI lists the more important teaching literature prepared and/or published by the Project.

TABLE XXI

Teaching Literature Published by the Project

1. A Primer for Programming with the MAD Language. Organick, Elliott I., Lithoprint, 65 pages, 1960.

   Copies Printed: Over 3000
   Distributed to: Students, faculty, participants
   Availability: Limited copies available from Project office

2. A Computer Primer for the MAD Language. Organick, Elliott I., 3rd printing, Lithoprint, 189 pages, 1961.

   Copies Printed: Over 1000
   Distributed to: Deans, computing centers, participants
   Availability: Ulrich's Bookstore, Ann Arbor

TABLE XXI, Continued

3. The Language of Computers. Galler, Bernard A., Lithoprint, 154 pages, 1961. (This material was prepared independently but the Project reproduced it in return for distribution privileges.)

   Copies Printed: 450
   Distributed to: Computing centers, participants
   Availability: McGraw-Hill Publishing Company (1962 edition)

4. Introduction to Digital Computing. Arden, Bruce W., Lithoprint, 232 pages, 1962. A collection of lecture material for Math. 373, prepared for publication during the fall semester of 1961 and used as the text for the course during the spring and fall semesters of 1962.

   Copies Printed: 1500
   Distributed to: Computing centers, participants
   Availability: Addison-Wesley Publishing Company (1963 edition)

5. Analog Computer Fundamentals. Navarro, Silvio O., Lithoprint, 102 pages, 1962.

   Copies Printed: 700
   Distributed to: Deans, participants
   Availability: Wadsworth Publishing Company (Belmont, California)

6. The Use of Logic in Solving Engineering Problems. Carnahan, B., Copi, Irving M., Katz, Donald L., Navarro, S. O., Squires, Robert G., and Franklin H. Westervelt, Lithoprint, 89 pages, 1962.

   Copies Printed: 700
   Distributed to: Deans, participants
   Availability: Limited copies available from Project office

7. Numerical Methods for Digital Computers. Carnahan, B., Luther, H. A., and James O. Wilkes (assisted by R. C. F. Bartels), Lithoprint, approximately 300 pages, 1963.

   Copies Printed: 800
   Distributed to: Deans, computing centers, and participants.
   Availability: Limited copies from Project office when printed

8. Computer Analysis of Structures. Berg, Glen V., Lithoprint, approximately 200 pages, 1963.

   Copies Printed: 700
   Distributed to: Deans, participants, civil engineering departments
   Availability: Limited copies from Project office when published

9. The ACT III Compiler System for the LGP-30 Digital Computer. Pease, Robert N., Lithoprint, 35 pages, June 1961.

   Copies Printed: 400
   Distributed to: Interested persons
   Availability: Limited copies from Project office

10. The BAD System. ed. by Organick, E. I. and R. P. Crabtree, Lithoprint, 27 pages, 1960. (Bendix Algo Decoder for the G-15 computer)

   Copies Printed: 200
   Distributed to: Interested persons
   Availability: Limited copies from Project office

11. Simulation of Production Processes on the LGP-30 Computer. Hancock, Walton M., Lithoprint, 1963.

   Distributed to: Industrial engineering departments, participants
   Availability: Limited copies from Project office when published

12. Management Decision Simulation for the LGP-30 Digital Computer. Drake, William D. Lithoprint, 40 pages, 1962.

   Copies Printed: 300
   Distributed to: Industrial engineering departments, participants
   Availability: Limited copies from Project office

13. A Modern History of Machine Organization. Rosin, Robert F., Lithoprint, 55 pages, 1962.

   Copies Printed: 200
   Distributed to: Interested persons
   Availability: Limited copies from Project office

14. An Introduction to the Theory and Application of Analog Computers. Howe, R. M. Lithoprint, 49 pages, 1960.

   Copies Printed: 500
   Distributed to: Interested persons
   Availability: Copies no longer available

Example Problems

One of the objectives of the Project was a "technical demonstration of the solution of computer-oriented problems suitable for illustrating principles in all branches of engineering."

Each participant was asked to prepare one or more example problems related to his field of interest. This served as a goal for his study and permitted distribution of his work to assist other faculty members. It is probable that most of these example problems will have only short term value; the good teacher usually desires to prepare his own problems and not use those prepared by others. Likewise, it should be appreciated that most of the example problems prepared for Project distribution were the first engineering problems which participants solved on a computer. The First Annual Report contained 45 problems, each including a problem statement, a discussion of the problem solution procedure, a flow diagram, and computer program with computer output. Most branches of engineering were represented in this group of problems.

The Second Annual Report included another 11 example problems in their entirety and abstracts of 86 additional problems for which solutions were available in the Project files.

Each curriculum report issued with this final Project report includes several example problems for that particular engineering discipline, making a total of 122 example problems for which solutions have been published.

Table XXXII lists all published and unpublished example problems by title, author, and, for those published, place of publication. For those problems for which the solution has not been published in one of the three references (First and Second Annual, and Final Reports), the original unedited solution submitted by the faculty member was put into a readable form and microfilmed. Persons desiring to see the unpublished problems may borrow a microfilm copy from the Project office.

Papers Published

Several papers published in various technical and educational journals have described the objectives and progress of the Project. The first paper, "Use of Computers in Engineering Undergraduate Teaching," presented by E. I. Organick at the Purdue meeting of the American Society of Engineering Education in June of 1960, described Project activities and included an example problem. A list of other papers published is given in Table XXII.

TABLE XXII

Papers Published by the Project

1. "Use of Computers in Engineering Undergraduate Teaching," Katz, D. L. and E. I. Organick, Jour. of Engr. Educ., Vol. 51, No. 3, December, 1960, p. 183 (23 pages). Reprints available from Project office.

2. "Conference Report on the Use of Computers in Engineering Classroom Instruction," April 29-30, 1960. Communications of the ACM, Vol. 3, No. 10, October, 1960, p. 522 (6 pages). Reprints no longer available.

3. "Impact on Industry of Engineering Graduates Who Have Used Computers in the Classroom," Katz, D. L. and E. I. Organick, Proc. of the National Electronics Conference, Vol. 16, October 10, 11, 12, 1960, p. 316 (7 pages). Reprints available from Project office.

4. "Progress in Teaching Engineering Students to Use Computers," Katz, D. L. and B. Carnahan, Soc. of Automotive Engineers, Summer meeting, 1961, St. Louis, Mo. (7 pages). Reprint No. 372-A. Reprints no longer available from Project office.

5. "Computers in Chemical Engineering Education," Lederman, P. B., Carnahan, B., and G. B. Williams. ASEE Summer School, Boulder, Colo., August, 1962. To be published in Chemical Engineering Education.

Unpublished Papers and Lectures by Project Personnel

Several persons associated with the Project have prepared unpublished papers for presentation at meetings or have given lectures or informal talks to small groups. A list of the more important of these papers and talks is given in Table XXIII.

TABLE XXIII

Unpublished Papers and Lectures by Project Personnel

1. "Project at The University of Michigan on the Use of Computers in Engineering Education," Katz, D. L., Galler, B. A. and E. I. Organick. Michigan Section, ASEE, April 23, 1960, Ann Arbor.

2. "Use of Computers in Engineering Education," Katz, D. L., Tulsa Section, ACM, February 23, 1961.

3. "Use of Digital and Analog Computers in Classroom Instruction," Katz, D. L., 26th Annual Meeting, Allegheny Section, Amer. Soc. Engr. Educ., Pittsburgh, April 21, 1961.

4. "Do Computers Upgrade Engineering Education?", Katz, D. L., Southern Regional Educational Board, Atlanta, Georgia, October 27, 1961.

5. "What Place Will Digital Computers Have in Teaching Science and Engineering?", Katz, D. L., Annual Conference on Higher Education in Michigan, November 14, 15, 1961.

6. "Do Computers Upgrade Engineering Education?", Katz, D. L., Pittsburgh Section, A.I.Ch.E., January 3, 1962.

7. "Increasing Competence of Engineering Graduates in the Use of Computers," Wilson, R. C., Seventh Annual Industry-Education Symposium, April 11, 1962, Ann Arbor.

8. "Computers in Engineering Education 1960-1964," Katz, D. L., Organick, E. I., Navarro, S. O., and B. Carnahan. Presented at the September, 1962 meeting of the ACM, Syracuse, New York. Copies of paper distributed at meeting and limited supply available from Project office.

TABLE XXIII, Continued

9. "Computers and Higher Education," Carnahan, B. Presented as part of a panel discussion at meeting of the Association of Midwest Universities, Argonne National Laboratories, June, 1961.

10. "Present and Future Trends of Computer Use in the Undergraduate Engineering Curricula," Carnahan, B. Presented to a study group on objective criteria in ceramic engineering education, sponsored by the ASEE at Boulder, Colorado, June 23, 1962.

11. "Computers in Metallurgical Engineering," Carnahan, B. Presented at a symposium sponsored by the American Society for Metals, New York, October 29, 1962.

12. "Project on Use of Computers in Engineering Education," Organick, E. I., IBM University Computing Center Directors' Seminar, Endicott, New York, July 18-22, 1960.

13. "The Philosophy Behind Integrating Computers into Engineering Education," Organick, E. I., Meeting of the Texas A. and M. Chapter of ASEE, October, 1960.

14. "Computers in Engineering Education," Organick, E. I., 4th Annual Symposium on Pilot Plant and Process Control, San Diego, April 4-5, 1962.

15. "New and Traditional Subject Matter for Introducing Undergraduate Engineering Students to Computing Techniques," Organick, E. I., Seminar before faculty and graduate students at UCLA, April 26, 1962.

16. "New and Traditional Subject Matter for Introducing Undergraduates to Digital and Analog Computing Techniques," Organick, E. I., Junior College Workshop in Engineering and Mathematics, Southern California Section, Los Angeles, California, April 27, 1962.

17. "The Professor and the Computer," Navarro, S. O., The Dean's Colloquy Series, The Pennsylvania State University College of Engineering and Architecture, University Park, Pennsylvania, March 19, 1962.

18. "The Use of Computers in Engineering Education," Navarro, S. O., Meeting of Engineering Department Heads, The University of Cincinnati, March 27, 1962.

19. "The Michigan Project for Integrating Computers into Engineering Education," Navarro, S. O., Southwest Universities' Computer Conference, The University of Texas, Austin, Texas, April 27-28, 1962.

Conferences

Three special conferences were held under Project auspices during 1960 and 1961. These are described below.

April 29-30, 1960:

A group of leaders in the field of machine computation were invited to the University to meet with the Computer Committee and Project participants. The meeting widened the Project staff's views of computer usage and reinforced earlier concepts concerning the value of having undergraduate students program solutions to their engineering problems. Some of the conclusions reached at the conference were:

1. The time has arrived when not only engineering students, but students in all fields should have an introductory course to appreciate the significance of machine computation and information processing.

2. Algorithmizing, perhaps more than any other kind of experience, reveals the structure of problems.

3. Professors who teach problem courses in which the computer is used must be able to program the problems themselves.

4. All engineering students should acquire the complete experience of defining problems, programming, coding, and examining the results from the computer. In all four years, the undergraduate should solve from 8 to 16 problems with a computer.

5. Beginning instruction on the use of computers should be given with problem- or procedure-oriented programming languages rather than with machine-oriented languages.

6. University financial support for computer equipment should include the teaching requirement as well as research.

Excerpts from the transcription of the tape recording of the conference were published in the Communications of the ACM in October, 1960.

September 12-13, 1960:

Following the first workshop, a conference was held in Ann Arbor, Michigan on September 12 and 13 for interested faculty people throughout the nation. Some 125 people from 78 different schools attended the conference. Exhibit VI shows the program. The First Annual Report was distributed to those attending the conference. The papers by R. W. Hamming, C. L. Miller, and J. C. Calhoun were lithoprinted and made available to those attending the conference and to others who requested copies later. Reprints are no longer available.

August 16-17, 1961:

Applications for the computer workshop conducted in early September, 1961 suggested that people were applying for the workshop who already had considerable knowledge of computer programming. It seemed unreasonable to include such people among those learning machine computation for the first time. Accordingly, it was decided to invite eleven faculty members, each from a different school, to a joint meeting with the summer participants on August 16 and 17, 1961.

Exhibit VII shows the schedule for the conference. The history of the Project and a description of the MAD language were outlined for the conferees. This was followed by joint meetings with the summer participants at which teaching of faculty and teaching of students were discussed in papers by S. O. Navarro and B. Carnahan. Texts of these papers were included in the Second Annual Report.

EXHIBIT VI

Program for Conference, September 12-13, 1960
The University of Michigan

September 12

Morning

Donald L. Katz, Presiding

Welcome:

Dean Glen Edmonson

Programs at Various Schools:

William J. Eccles	Purdue University
J. R. Fincher	Georgia Institute of Technology
Tom Puckett	University of Oklahoma
Charles Scheffey	University of California
C. L. Miller	Massachusetts Institute of Technology
A. J. Perlis	Carnegie Institute of Technology

Afternoon

Gordon J. Van Wylen, Presiding

The Program at The University of Michigan:

Overall Program	Donald L. Katz
Training of Faculty	Elliott I. Organick
Training of Students	Bernard A. Galler
Computing Facilities and How They are Used	Norman R. Scott
Integration of Computers into Curriculum	Glen V. Berg
Example Problems	Dale F. Rudd

September 13

Morning

Saul Gorn and Elliott I. Organick, Presiding

OVERALL VIEW OF COMPUTERS IN A UNIVERSITY

Computer Appreciation Courses: R. J. Hamming, Bell Telephone Laboratories and Past President, Association for Computing Machinery

Response: A. J. Perlis, Director, Computing Center, Carnegie Institute of Technology

Open Discussion

Adjustments in the Mathematics Curriculum: F. M. Tiller, Dean of Engineering, and E. L. Michaels, Professor of Electrical Engineering, University of Houston

Response: R. C. F. Bartels, Director, Computing Center, The University of Michigan

Open Discussion

Appropriate Level of University Support: J. C. Calhoun, Vice Chancellor for Engineering, Texas A. and M. College

EXHIBIT VI, Continued

Afternoon

GROUP SESSIONS TO DISCUSS EXAMPLE PROBLEMS (The Michigan Union)

Aeronautical, Astronautical, and Meteorological Engineering	R. M. Howe, J. G. Eisley, E. S. Epstein
Chemical and Metallurgical Engineering	J. J. Martin, D. F. Rudd, K. H. Coats
Civil Engineering and Engr. Mechanics	G. V. Berg, V. L. Streeter, W. P. Graebel
Electrical Engineering	N. R. Scott, R. K. Brown
Industrial Engineering	R. C. Wilson, W. M. Hancock
Mechanical Engineering	F. H. Westervelt, J. R. Pearson

EXHIBIT VII

Program for Conference, August 16-17, 1961
The University of Michigan

August 16:

Morning

Registration

D. L. Katz introduced the Project staff and described Project developments and goals. B. Carnahan described briefly the grammar and vocabulary of the MAD language. S. O. Navarro and D. F. Jankowski discussed analog computer facilities and gave a demonstration problem solution on a small analog computer.

Afternoon

Dean G. V. Edmonson, Presiding

Teaching the Use of Computers to the Faculty - S. O. Navarro

Teaching Engineering Students to Use Computers - B. Carnahan

Tour of Computing Center

Evening

Silvio O. Navarro, Presiding

Operating a Small Departmental Computing Center - R. V. Evans, Department of Industrial Engineering

Preparation of Visual Aids for Teaching the Use and Operation of Computing Equipment - F. H. Westervelt, Department of Mechanical Engineering

August 17:

Morning

Elliott I. Organick, Presiding

The eleven example problems included in Part II, Appendix E, pages 189-302 of the Second Annual Report, were presented by the authors. Summaries of other problems done by summer participants were reviewed by disciplines.

LUNCHEON: Address by R. C. F. Bartels, Director, Computing Center, and Professor of Mathematics, The University of Michigan

Afternoon

Donald L. Katz, Presiding

Open Discussion as Follows:

Computer Appreciation - S. O. Navarro, Discussion Leader
Computer Programming and the Logic of Problem Solving - E. I. Organick, Discussion Leader
Adjustments in Mathematics Resulting from Computer Usage - B. Carnahan, Discussion Leader
Integration of Computers into Individual Disciplines - Speakers from several engineering areas presented their views on integrating computers into their disciplines.

VIII. HISTORY AND ADMINISTRATION OF THE PROJECT

Historical information is presented to provide a background for those not familiar with the Project and its activities. It may be of interest to those conducting similar educational projects and includes factual information in essentially chronological order.

Historical Development and Time Schedule

In the fall of 1958, an informal faculty group in the College of Engineering at The University of Michigan was assembled by Professor D. L. Katz and Professor R. R. White to consider the place of electronic computers in undergraduate engineering education. In December of that year the first draft of a Project proposal was prepared suggesting that computers be used in solving selected problems in the required engineering courses.

In February, 1959, lectures on programming the IBM 650 computer using the GAT language (written at The University of Michigan) were given by B. A. Galler for students and faculty in Chemical and Metallurgical Engineering with about 250 in attendance. Each problem course in the Department included an assignment of a problem appropriate for solution on the computer. In some classes, students succeeded in solving the problem on the IBM 650; in others the instructor prepared a demonstration solution. A closed circuit T.V. program of a tour through the Computing Center and an example problem solution was given for the benefit of some 400 students and faculty in April, 1959.

In June of 1959, the original proposal was enlarged to include the experiences of the pilot study and a proposal for a demonstration project was submitted to The Ford Foundation. By this time the faculty group had been enlarged and officially designated by Dean S. S. Attwood as the Computer Committee of the College of Engineering.

On October 20, 1959, a grant of $900,000 was made to the University by The Ford Foundation to support the proposed project. The grant included funds for training faculty members from other schools as well as for the demonstration of computer use at The University of Michigan.

During the fall semester of 1959, FORTRAN programming lectures were given by B. A. Galler and selected courses experimented with student use of the new IBM 704 computer which had been installed during the summer of 1959. Elliott I. Organick, Director of the Computing and Data Processing Center at the University of Houston was appointed as Assistant Director of the Project in charge of technical activities from February 1, 1960 through September 15, 1960.

When Dr. Organick arrived in Ann Arbor, a compiler for the MAD language was being completed. It was fully operational for the IBM 704 in early March. He gave a beginning level lecture series at the start of the semester and prepared notes on MAD programming. These notes in subsequent revised editions became A Computer Primer for the MAD Language. A small group of Michigan faculty members were released from part of their teaching duties and along with W. S. Clouser, Assistant Professor of Engineering Mechanics from the University of Wisconsin, comprised the first faculty study group. See Tables XXIX and XXX for a list of all Project participants. E. I. Organick and his student assistants were available for instruction in programming and solving classroom problems.

A Royal McBee LGP-30 computer and later a Bendix G-15 computer were obtained on consignment for use on the Project. Modifications were made in the ACT compiler, and the ACT language was taught to selected groups. A set of BAD lecture notes was prepared to assist in introducing students to the ALGO language for the Bendix G-15. To supply needed analog equipment, five Applied Dynamics AD-1 computers, three Reeves computers and one Applied Dynamics AD-64 computer were purchased by the Project during the summer of 1960.

The program for the summer of 1960 was one of full time study for fifteen teachers from other schools and three from Michigan. Brice Carnahan joined the Project and assisted E. I. Organick with the instruction. R. C. F. Bartels gave a series of thirteen one and one-half hour lectures on numerical analysis and R. M. Howe assisted by D. T. Greenwood introduced the group to analog computation in a series of lecture and laboratory sessions. N. R. Scott gave four two-hour lectures on the logical design of digital computers. A major effort during the summer was the preparation of the First Annual Report including 45 example problems.

The first faculty programming workshop was held on September 5-9, 1960 with the professors listed in Table XXX in attendance. The workshop was followed by a two-day conference for some 125 persons on the use of computers in engineering instruction. Silvio O. Navarro, at that time Assistant Director of the Computing Center at the University of Kentucky, joined the Project in September of 1960 and Elliott I. Organick returned to the University of Houston.

During the school year 1960-1961, the evening lecture series and faculty study groups were continued by S. O. Navarro and B. Carnahan at the beginning of each semester.
Faculty participants are listed in Table XXX. Invitations for participation in the faculty program for the summer of 1961 elicited 213 applications. Forty-five faculty members from twenty-nine schools and ten from The University of Michigan were selected from the applicants

for the nine-week study program. Those attending are listed in Table XXX. E. I. Organick re-joined the Project staff for the summer and Prof. W. M. Kincaid of the Mathematics Department taught numerical analysis for three weeks in two-hour periods each day. R. C. F. Bartels followed with a week of lectures on partial differential equation solutions. A conference of representatives of many schools met with the participants on August 16-17, 1961 to review the progress of the Project. A second programming workshop for faculty was held September 4-12, 1961 with the 42 attendees shown in Table XXX. S. O. Navarro returned to the University of Kentucky on September 15, 1961 and Brice Carnahan assumed all teaching and technical responsibilities as the Assistant Director.

The 1961-1962 school year followed the earlier pattern of giving a lecture series for students at the beginning of each semester and having a faculty study group, with technical assistance provided for all interested faculty. The Second Annual Report which was issued in the fall of 1961 included eleven more example problems. Each educational program in the College was asked to prepare a report on the use of computers for instruction of students in that discipline. A survey of all accredited engineering school deans was made in March-June, 1962 to find the extent to which computers were being included in their educational programs. E. I. Organick and S. O. Navarro returned to Ann Arbor for short periods in the summer of 1962 to assist in the preparation of this final report.

During the summer of 1962, in addition to preparation of the final report, six major Project-sponsored efforts were undertaken to employ computers in advanced instruction. Prof. H. A. Luther of the Mathematics Department at Texas A. and M. College, J. O. Wilkes of the Department of Chemical and Metallurgical Engineering at The University of Michigan, and Brice Carnahan prepared a text on numerical methods which follows in several sections a set of numerical analysis notes originally prepared by R. C. F. Bartels for the summer programs of 1960 and 1961. Prof. I. M. Copi of the Philosophy Department, F. H. Westervelt of the Mechanical Engineering Department, S. O. Navarro, R. C. Wilson of the Industrial Engineering Department, R. G. Squires of the Chemical and Metallurgical Engineering Department, B. Carnahan and D. L. Katz looked into the use of formal logic in solving engineering problems. Prof. Howard F. Rase of The University of Texas joined the group for the week of June 3-8. Four professors, G. V. Berg of the Civil Engineering Department, K. Chuang of the Electrical Engineering Department, F. G. Hammitt of the Nuclear Engineering Department, and W. H. Hancock of the Industrial Engineering Department, were individually supported to study the use of computers in advanced courses in their subject areas.

During the year 1962-1963, Brice Carnahan has been giving the lecture series for students and providing technical assistance for the faculty. As of June 30, 1963, all phases of the Project will be concluded. An overall time table is shown in Table XXIV.

TABLE XXIV

Time Table for the Project

October 1958	Informal committee studies use of computers in instruction.
February 1959	B. A. Galler lectures to students on programming and pilot study in Department of Chemical and Metallurgical Engineering.
June 1959	Proposal to The Ford Foundation.
October 1959	Grant made to The University of Michigan by The Ford Foundation.
February 1960	E. I. Organick directs initial instructional program under grant.
April 1960	Conference of experts reviews Project.
Summer 1960	Full time study for 18 professors; Brice Carnahan joins Project.
September 1-10, 1960	Workshop for 59 professors.
September 1960	First Annual Report made to conference of 125 educators in Ann Arbor.
September 15, 1960	S. O. Navarro appointed Assistant Director.
June 1961	A summer program for 55 professors taught by S. O. Navarro, E. I. Organick, and B. Carnahan.
August 16-17, 1961	Conference of participants and representatives of other schools.
September 1-8, 1961	Programming workshop for 42 professors.
September 1961	Brice Carnahan appointed Assistant Director.
December 15, 1961	Second Annual Report issued.
Summer 1962	Study groups on numerical methods , logic in solving problems, and computer use in advanced courses in engineering.
December 1962	Final report issued.
June 30, 1963	Project concludes.

Internal Activities and Special Programs

As indicated in the historical statement, a Computer Committee was appointed in the fall of 1959 with the Project Director as Committee Chairman. This Committee consisted of one representative from each of the professional departments in the College of Engineering and two representatives of the Computing Center. Meetings were held at approximately one-month intervals during the school year; minutes were distributed to the Committee members, department chairmen, and administrative officers of the University. Such items as selection of Assistant Directors for the Project, the handling of the selection of participants, and the purchase of equipment were discussed thoroughly, and any final action taken, approved by the Committee. Most members of the Committee made a significant contribution to the Project by assisting in one or more of its activities.

Starting in the spring of 1960 and continuing through the fall semester of 1962, special luncheon meetings were held at noon almost every Thursday for Project participants and all interested members of the engineering faculty. The programs at these luncheons were varied. Faculty throughout the University were invited to describe their use of computers, usually in research. Participants from other schools often presented work which they had done prior to coming to the University. Some meetings were devoted to the description of changes in language or in Computing Center operation. Some 40 luncheon meetings in all were held with an attendance varying from 25 to 60 with an average of perhaps 35.

Informal instruction was given to faculty and students of the University by the Assistant Director and student assistants. A large block of time not previously mentioned was devoted to personal tutoring of participants, other faculty members, and students both within the College of Engineering and throughout the University.

Special meetings were held within the College of Engineering to bring together the program advisors for the various curricula, participants, the Computer Committee, and Project personnel. At the end of the spring semester of 1961, a one-day meeting was devoted to a review of the progress being made in instruction, particularly in the introductory digital computer course, Math. 373, and its relationship to the Project. Again, in February of 1962, a one-day meeting was held to review the work being done by faculty in the College of Engineering and by participants. In the spring semester of 1961, two one-day meetings were held to give a thorough presentation to Department Chairmen and senior faculty personnel who had not otherwise been associated with the Project. The day's program reviewed digital computer languages, the use of the analog computer, and the place of computers in the curriculum. Example problems were also reviewed and distributed.

At the April 1960 conference, Dr. Richard W. Hamming voiced the opinion that all college students in today's world should take a computer appreciation course. He was invited to present a paper on the subject at the conference held in Ann Arbor, September 12-13, 1960. His paper, which has been widely distributed, included a suggested outline for a 36-period course. Topics suggested are history of computing, simple coding ideas, statistics and data reduction, information retrieval, machine translation, automatic coding, linguistics, the need and role of redundancy, the idea of random, games, machine-made music, sumulation of experiments, biological and medical research, Boolean algebra, business applications, political and social consequences, and general implications for creativity. The full list with subtopics is included in an article by G. E. Forsythe in the Journal of Engineering Education, Vol. 52, No. 3, December 1961, p. 177.

During the 1960-1961 school year, four lecturers were brought to the University, Their public lectures, given as a series entitled "Computer Appreciation Lectures," are listed in Table XXV.

TABLE XXV

Computer Appreciation Lectures

1. "Application of Computers to Music," Lejaren A. Hiller, Jr., Res. Asst. Prof. of Music, University of Illinois - February 23, 1961.

2. "Language Translation with Computers," Anthony G. Oettinger, Assoc. Prof. of Applied Math. and of Linguistics, Harvard University - March 23, 1961.

3. "Computers and Artificial Intelligence," Marvin L. Minsky, Prof. of Math. and Computation Center Associate, Massachusetts Institute of Technology - April 27, 1961.

4. "Medical Diagnosis with Computers," Robert S. Ledley, President, National Biomedical Research Foundation, Inc. - May 18, 1961.

Selection of Participants and the Handling of Appointments and Expenses

Early Project reports issued an invitation to faculty members from other schools to apply for attendance at workshop, summer, and full semester training programs. Prospective participants were asked to fill out a form giving information such as position, education, professional experience, courses taught, publications, and knowledge of or experience with computers. In the early stages of Project development, essentially all requests were honored. The most difficult problem was the selection of summer participants for 1961. There were 213 applications and funds and facilities for only 55 men. Several factors were considered in selecting the personnel. The prime criterion was applicant qualification. An attempt was made to assist specific schools which had expressed a strong interest in the Project and had taken part in early deliberations. It was also thought advisable to have as many schools represented as possible. During the summer of 1961, the group of 55 represented 30 schools from the United States and Canada.

Table XXIX lists all participants by school and rank; Tables XXVIIa, b, and c summarize the overall distributions by academic rank and field. Table XXVIII shows the number of Michigan and non-Michigan faculty taking part in the various programs.

The original grant to the University stated that visiting professors should come to Ann Arbor on a "no loss-no gain" basis, exclusive of consulting income. This was interpreted to mean that the teacher should receive the equivalent of his salary at his home institution plus an additional amount to cover extra expenses incurred by traveling to and living in Ann Arbor. A worksheet was prepared for each participant including such items as extra housing expense, travel expense, other expenses, and income tax on expenses (since the expenses were included as salary, and "loss" would have resulted if the tax on the extra expenses had not been included). For those participating in a semester program the expenses included contributions to retirement programs for those not associated with the TIAA plan. For those in TIAA, contributions were made directly to their accounts.

Housing was procured on an informal basis with the assistance of a local real estate firm. The Director and Project secretary, in many cases, visited apartment houses or homes for prospective participants. Some faculty members chose to live in University married student housing. When a participant wished to rent an apartment or home from an individual in Ann Arbor, the Project staff put him in contact with the owner to make final arrangements. With 73 persons living in Ann Arbor for either two or five month periods, only two or three problems arose in making housing arrangements.

Those attending workshops or conferences were paid travel and living expenses while in Ann Arbor.

IX. FINANCIAL STATEMENT

A financial statement indicating the major distribution of Project expenditures is given in Table XXVI. Each item has explanatory notes attached. This statement was prepared in advance of the conclusion of the Project; it was necessary to estimate distribution for some 2% of the total amount involved.

TABLE XXVI

Financial Statement*
Expenditures by Categories
October 1959 - June 30, 1963

1.	Visiting Faculty	$227,462
2.	Faculty from University of Michigan staff	115,348
3.	Director, Assistant Directors, Secretarial	118,372
4.	Assistants for Instruction	69,876
5.	Employee Benefits	21,212
6.	Support of Computing Center	134,939
7.	Equipment: Analog, lecture machines, office	52,890
8.	Supplies: Postage, services on small computers, etc.	26,028
9.	Lithoprinting and reproducing reports	27,160
10.	Travel including all workshop expenses	27,130
11.	Supporting service	79,583
	Total	$900,000

* Final costs in some categories include estimated amounts.

Notes on Financial Statement

Item 1: Thirteen visiting faculty members were at the University for a semester and 60 were in Ann Arbor for two months in the summer. Their salaries included the extra expenses of coming to Ann Arbor on a no gain-no loss basis.

Item 2: Most of the 43 faculty on semester appointments were for one-half or one-third time; 13 faculty spent full time for a summer.

Item 3: The Director's appointment on the Project was for 40-50% of his time for a period of three and one-half years. The Assistant Directors were full time. They served as technical directors and their efforts were in the instruction and preparation of teaching materials. Some 30% of this item might be classified as administrative as compared with instructional.

Item 4: Student assistants were provided for instruction in both analog and digital computing. Students did much of the checking of example problems and proofreading of published material. A student assistant was maintained in the Computing Center as well.

Item 5: Employee benefits include TIAA contributions and social security for all personnel except summer participants.

Item 6: Contributions were made to the support of the Computing Center which provided computing services for participating faculty, the Project staff, and engineering students.

Item 7: Eight small instructional analog computers and one intermediate analog unit were purchased. Two lecture machines for teaching the mechanics of card punching, reproduction, and listing were also purchased. Some additional office equipment was required.

Item 8: Maintenance services for the Royal McBee LGP-30 and the Bendix G-15 are included. Postage for the distribution of reports was a significant item.

Item 9: This item consists of outside contract work for printing from 700 to 2500 copies of some 2600 pages of material.

Item 10: Workshop expenses for participants constitute some 85% of this item.

Item 11: A general charge by the University for such services as payroll, accounting, administration, libraries, etc.

X. MASTER TABLES

This section contains summary lists of faculty participants, colleges on the mailing lists, and example engineering problems as follows:

1. Table XXVII summarizes the number of Project participants of each academic rank and departmental affiliation. Table XXVIII is a list of the number of faculty taking part in each of the Project's training programs.

2. Tables XXIX and XXX contain the name, rank, departmental and college affiliation and period of activity of engineering faculty members who took part in the Project's various faculty training programs during the period 1960-1962. Table XXIX lists participants according to alphabetic arrangement of school name, with faculty names arranged alphabetically for each school. Table XXX is the same list, reordered according to period of Project association.

3. Table XXXIa is the master list of American and Canadian engineering schools which regularly received most of the Project's published literature or which actively participated in the Project by sending faculty members to Ann Arbor for training programs, conferences, informal talks, etc. Table XXXIb is a list of additional American and Canadian schools which have received information of some form from the Project, through a library, computing center, or individual faculty request. Table XXXIc is an incomplete list of foreign colleges and universities to which the Project has sent information on request.

4. Table XXXII is a master list of all example problems published by the Project. The problems are listed by subject area and include title, author and source. In some cases, the problems are available only on a microfilm, which may be borrowed by writing the Project office.

TABLE XXVIIa

Academic Rank and Departmental Affiliation of Project Participants

Non-University of Michigan Faculty

Rank	AE	ChE	CE	ME	EE	MMM*	IE	EM+	NA@	Other	Total
Dean										5	5
Dept. Head		2		2	5		1	1			11
Prof.		4	8	3	7		2	1		7	32
Assoc. Prof.		4	6	13	11	1	4	7		2	48
Asst. Prof.	3	7	11	6	6	4	3	2	1	6	49
Instructor		1	1	2	2		1	1		2	10
Other		1			1		1			2	5
Total	3	19	26	26	32	5	12	12	1	24	160

TABLE XXVIIb

Michigan Faculty

Rank	AE	ChE	CE	ME	EE	MMM*	IE	EM	NA	Other	Total
Dean											
Dept. Head		1		1							2
Prof.	1	5	3	3	7	1	2	1		1	24
Assoc. Prof.	1	2	1	3	2		1	1		1	12
Asst. Prof.		2	2	2	1	1	3	2	2	1	16
Instructor			1								1
Other										1	1
Total	2	10	7	9	10	2	6	4	2	4	56

TABLE XXVIIc

All Faculty

Rank	AE	ChE	CE	ME	EE	MMM*	IE	EM	NA	Other	Total
Dean										5	5
Dept. Head		3		3	5		1	1			13
Prof.	1	9	11	6	14	1	4	2		8	56
Assoc. Prof.	1	6	7	17	13	1	5	8		3	60
Asst. Prof.	3	9	13	7	7	5	6	4	3	7	65
Instructor		1	2	2	2		1	1		2	11
Other		1			1		1			3	6
Total	5	29	33	35	42	7	18	16	3	28	216

* Metallurgical, Materials, and Mining Engineering
\+ Engineering Mechanics
@ Naval Architecture

TABLE XXVIII

Number of Faculty Participants by Period of Project Activity

Project Activity	Non-Michigan Faculty	Michigan Faculty	Total
Spring Semester 1960	1	9	10
Summer Program 1960	15	3	18
Workshop 1960	50	9	59
Fall Semester 1960	4	15	19
Spring Semester 1961	6	11	17
Summer Program 1961	45	10	55
Workshop 1961	39	3	42
Fall Semester 1961	2	8	10
Total	162*	68*	230*

* These numbers are somewhat larger than appear in the previous table because 2 non-Michigan and 12 Michigan faculty people participated in more than one activity.

TABLE XXIX

Faculty Participants in Project Activities
Arranged by College or University Affiliation

NAME	RANK	DEPARTMENT	UNIVERSITY	PERIOD OF PARTICIPATION
Dalla Lana, I. B.	Assoc. Prof.	Chem. Engr.	Alberta, U. of	Workshop 1960
Duby, John	Assoc. Prof.	Mech. Engr.	Alberta, U. of	Summer 1960
Glockner, Peter	Asst. Prof.	Civil Engr.	Alberta, U. of	Summer 1961
Kelly, Donald H.	Asst. Prof.	Elec. Engr.	Alberta, U. of	Summer 1961
Quon, Donald	Assoc. Prof.	Chem. Engr.	Alberta, U. of	Workshop 1960
Rodkiewicz, C. M.	Asst. Prof.	Mech. Engr.	Alberta, U. of	Workshop 1960
Warwaruk, Joseph	Asst. Prof.	Civil Engr.	Alberta, U. of	Summer 1961
Youdelis, W. V.	Asst. Prof.	Min. & Met.	Alberta, U. of	Workshop 1960
Prawel, Sherwood, Jr.	Asst. Prof.	Engr.	Buffalo, U. of	Workshop 1961
Rollins, Carl	Instructor	Elec. Engr.	Buffalo, U. of	Workshop 1961
Hazlett, Thomas H.	Prof.	Indus. Engr.	Calif., U. of (Berkeley)	Workshop 1961
Lapsley, James T., Jr.	Assoc. Prof.	Indus. Engr.	Calif., U. of (Berkeley)	Workshop 1960
Paulling, J. R.	Asst. Prof.	Nav. Arch.	Calif., U. of (Berkeley)	Summer 1961
Ward, Stanley H.	Assoc. Prof.	Min. Explor.	Calif., U. of (Berkeley)	Workshop 1960
Rasof, Bernard	Assoc. Prof.	Appl. Mech.	Calif., U. of (L.A.)	Summer 1961
Au, Tung	Assoc. Prof.	Civil Engr.	Carnegie Inst. of Tech.	Summer 1960
Bugliarello, George	Asst. Prof.	Civil Engr.	Carnegie Inst. of Tech.	Workshop 1960
Converse, Alvin O.	Asst. Prof.	Chem. Engr.	Carnegie Inst. of Tech.	Summer 1961
Liu, C. Y.	Asst. Prof.	Mech. Engr.	Carnegie Inst. of Tech.	Summer 1960
Brandt, Donald G.	Asst. Prof.	Civil Engr.	City U. of New York	Spring 1961
Eitzer, Demos	Lecturer	Elec. Engr.	City U. of New York	Summer 1960
Hartman, Paul	Prof.	Civil Engr.	City U. of New York	Workshop 1960
Hyman, Seymour	Asst. Dean	School of Engr.	City U. of New York	Workshop 1960
List, Harvey L.	Asst. Prof.	Chem. Engr.	City U. of New York	Summer 1960
Lowen, Gerard G.	Asst. Prof.	Mech. Engr.	City U. of New York	Summer 1961
Menkes, Sherwood B.	Assoc. Prof.	Mech. Engr.	City U. of New York	Workshop 1960
Patell, Minocher K. N.	Asst. Prof.	Chem. Engr.	City U. of New York	Workshop 1960
Pei, Ming L.	Prof.	Civil Engr.	City U. of New York	Fall 1960
Pfeffer, Robert	Lecturer	Chem. Engr.	City U. of New York	Summer 1961
Pistrang, Joseph	Asst. Prof.	Civil Engr.	City U. of New York	Summer 1961
McHugh, Edward	Prof.	Mech. Engr.	Clarkson Coll. of Tech.	Workshop 1961
Brand, Ronald	Prof.	Mech. Engr.	Connecticut, U. of	Workshop 1960
Vrana, Norman	Assoc. Prof.	Elec. Engr.	Cornell U.	Workshop 1961
Heckbert, Albert I.	Assoc. Prof.	Elec. Engr.	Dartmouth College	Workshop 1961
Howerton, Murlin T.	Prof.	Chem. Engr.	Denver, U. of	Workshop 1961
Jessup, Bob A.	Prof., Dept. Head	Elec. Engr.	Detroit Inst. of Tech.	Workshop 1961
Ahlquist, Robert	Prof.	Elec. Engr.	Detroit, U. of	Workshop 1960
Birturk, Yavuz	Instructor	Elec. Engr.	Detroit, U. of	Workshop 1960
Szczepaniak, Edward A.	Asst. Prof.	Aero. Engr.	Detroit, U. of	Workshop 1960
Woodworth, Forrest M.	Asst. Prof.	Engr. Graphics	Detroit, U. of	Workshop 1961
Uhl, Vincent W.	Prof.	Chem. Engr.	Drexel Inst. of Tech.	Workshop 1961
Gorton, Charles W.	Assoc. Prof.	Mech. Engr.	Georgia Inst. of Tech.	Workshop 1960
May, George D.	Asst. Prof.	Civil Engr.	Georgia Inst. of Tech.	Fall 1960
White, Frank M.	Asst. Prof.	Aero. Engr.	Georgia Inst. of Tech.	Summer 1960
Aucoin, Anthony A.	Prof.	Math.	Houston, U. of	Summer 1961
Eichberger, L. C.	Asst. Prof.	Mech. Engr.	Houston, U. of	Fall 1961
Elrod, J. T.	Prof., Dept. Head	Indus. Engr.	Houston, U. of	Spring 1961
Henry, Robert J.	Instructor	Civil Engr.	Houston, U. of	Spring 1961
Hoff, John	Prof.	Civil Engr.	Houston, U. of	Workshop 1960
Kittinger, William T.	Assoc. Prof.	Elec. Engr.	Houston, U. of	Spring 1961
Michaels, E. L.	Prof., Dept. Head	Elec. Engr.	Houston, U. of	Summer 1961, Workshop 1960
Michalopoulos, C. D.	Instructor	Mech. Engr.	Houston, U. of	Summer 1961
Prengle, H. W.	Prof.	Chem. Engr.	Houston, U. of	Workshop 1960
Tiller, F. M.	Dean	School of Engr.	Houston, U. of	Workshop 1960
White, Ardis	Assoc. Prof.	Civil Engr.	Houston, U. of	Summer 1961
Anderson, George P.	Lecturer	Indus. Engr.	Illinois, U. of	Summer 1961
Bailey, Albert D.	Prof.	Elec. Engr.	Illinois, U. of	Workshop 1961
Davidson, Raymond A.	Asst. Prof.	Elec. Engr.	Illinois, U. of	Summer 1961
Scheck, D. C.	Asst. Prof.	Gen. Engr.	Illinois, U. of	Workshop 1960
Shoemaker, Edward M.	Assoc. Prof.	Appl. Mech.	Illinois, U. of	Summer 1961
Chu, Kuang-Han	Assoc. Prof.	Civil Engr.	Illinois Inst. of Tech.	Summer 1961
Quinn, Cleo J.	Instructor	Mech. Engr.	Indiana Tech. College	Workshop 1961
Boctor, Magdy L.	Instructor	Engr. Graphics	Iowa State U.	Workshop 1961

TABLE XXIX, Continued

NAME	RANK	DEPARTMENT	UNIVERSITY	PERIOD OF PARTICIPATION
Beckett, Royce E.	Assoc. Prof.	Mech. & Hydraul.	State U. of Iowa	Summer 1960
Howe, J. W.	Prof.,Dept. Head	Mech. & Hydraul.	State U. of Iowa	Fall 1961
Trummel, J. Merle	Assoc. Prof.	Mech. Engr.	State U. of Iowa	Workshop 1961
Graham, Peter J.	Asst. Prof.	Elec. Engr.	Kentucky, U. of	Workshop 1961
Romanowitz, Alex	Prof.,Dept. Head	Elec. Engr.	Kentucky, U. of	Workshop 1960
Snoblin, Kenneth	Prof., Head	Computer Lab.	Lawrence Inst.of Tech.	Workshop 1960
Herbich, John B.	Assoc. Prof.	Civil Engr.	Lehigh U.	Workshop 1961
Sword, E. C.	Asst. Prof.	Civil Engr.	Lehigh U.	Workshop 1960
Wenzel, L. A.	Assoc. Prof.	Civil Engr.	Lehigh U.	Workshop 1960
Manning, Thomas A.,Jr.	Instructor	Engr. Mech.	Louisiana State U.	Workshop 1961
Chen, A. T.	Prof.	Math.	Louisville, U. of	Workshop 1960
Bett, Gilbert W.	Assoc. Prof.	Elec. Engr.	Massachusetts, U. of	Summer 1961
Lindsey, E. E.	Prof.,Dept. Head	Chem. Engr.	Massachusetts, U. of	Workshop 1961
Peatman, John B.	Asst. Prof.	Elec. Engr.	Missouri Sch. of Mines & Metallurgy	Summer 1961
Akerman, J. R.	Assoc. Prof.	Mech. Engr.	Michigan, U. of	Spring 1961
Balzhiser, R. E.	Asst. Prof.	Chem. Engr.	Michigan, U. of	Fall 1960
Berkeley, Richard W.	Asst. Prof.	Indus. Engr.	Michigan, U. of	Fall 1960, Workshop 1961
Berry, R. M.	Prof.	Civil Engr.	Michigan, U. of	Summer 1961
Bigelow, W. C.	Prof.	Sci. Engr.	Michigan, U. of	Fall 1961,Wkshp.1[illegible]
Brater, E. A.	Prof.	Civil Engr.	Michigan, U. of	Workshop 1960
Bolt, J. A.	Prof.	Mech. Engr.	Michigan, U. of	Summer 1961
Boutwell, F. K.	Asst. Prof.	Mech. Engr.	Michigan, U. of	Fall 1960
Brown, R. K.	Prof.	Elec. Engr.	Michigan, U. of	Spring 1960
Brownell, L. E.	Prof.	Chem. Engr.	Michigan, U. of	Fall 1961, Workshop 1960
Carey, J. J.	Prof.	Elec. Engr.	Michigan, U. of	Fall 1960, Summer 1960
Churchill, S. W.	Prof.,Dept. Head	Chem. Engr.	Michigan, U. of	Fall 1961
Clark, John A.	Prof.	Mech. Engr.	Michigan, U. of	Fall 1961
Cutrona, L. J.	Prof.	Elec. Engr.	Michigan, U. of	Spring 1961
Debler, Walter R.	Assoc. Prof.	Engr. Mech.	Michigan, U. of	Fall 1961
Dingle, A. N.	Assoc. Prof.	Meteorology	Michigan, U. of	Fall 1961
Eisley, J. G.	Assoc. Prof.	Aero. Engr.	Michigan, U. of	Fall 1960, Summer 1960
Enns, John H.	Prof.	Engr. Mech.	Michigan, U. of	Spring 1960
Epple, A. B.	Assoc. Prof.	Mech. Engr.	Michigan, U. of	Fall 1960
Evans, R. V.	Asst. Prof.	Indus. Engr.	Michigan, U. of	Spring 1960
Farris, H. W.	Assoc. Prof.	Elec. Engr.	Michigan, U. of	Fall 1960, Workshop 1960
Gage, J. A.	Prof.	Indus. Engr.	Michigan, U. of	Spring 1961
Gordon, Kenneth F.	Assoc. Prof.	Chem. Engr.	Michigan, U. of	Workshop 1960
Graebel, W. P.	Asst. Prof.	Engr. Mech.	Michigan, U. of	Spring 1961
Gyorey, G. L.	Asst. Prof.	Nuclear Engr.	Michigan, U. of	Spring 1960
Hancock, W. M.	Prof.	Indus. Engr.	Michigan, U. of	Spring 1960, Summer 1960
Harris, R. B.	Assoc. Prof.	Civil Engr.	Michigan, U. of	Fall 1960
Heimbach, C. L.	Instructor	Civil Engr.	Michigan, U. of	Workshop 1961
Isakson, Gabriel	Prof.	Aero. Engr.	Michigan, U. of	Summer 1961
Johnson, Clyde	Assoc. Prof.	Indus. Engr.	Michigan, U. of	Fall 1960
Jones, D. L.	Lecturer	Meteorology	Michigan, U. of	Workshop 1960
Kaljian, M. J.	Asst. Prof.	Engr. Mech.	Michigan, U. of	Summer 1961
Kazda, L. F.	Prof.	Elec. Engr.	Michigan, U. of	Fall 1961
Kempe, L. L.	Prof.	Chem. Engr.	Michigan, U. of	Workshop 1960
Macnee, A. B.	Prof.	Elec. Engr.	Michigan, U. of	Fall 1960, Workshop 1960
Maugh, L. C.	Prof.	Civil Engr.	Michigan, U. of	Fall 1960
McMullen, C. W.	Assoc. Prof.	Elec. Engr.	Michigan, U. of	Fall 1960,Spr.1961
Merte, Herman, Jr.	Asst. Prof.	Mech. Engr.	Michigan, U. of	Spring 1960
Michelsen, Finn	Asst. Prof.	Naval Arch.	Michigan, U. of	Spring 1961
Miller, Murray H.	Asst. Prof.	Elec. Engr.	Michigan, U. of	Spring 1961
Mirsky, William	Assoc. Prof.	Mech. Engr.	Michigan, U. of	Fall 1960
Mosher, Raymond F.	Prof.	Elec. Engr.	Michigan, U. of	Summer 1961
Pearson, J. R.	Prof.	Mech. Engr.	Michigan, U. of	Spring 1961
Pehlke, Robert D.	Asst. Prof.	Met. Engr.	Michigan, U. of	Spring 1960
Peterson, G. E.	Prof.	Elec. Engr.	Michigan, U. of	Spring 1961
Rudd, Dale F.	Asst. Prof.	Chem. Engr.	Michigan, U. of	Spring 1960

TABLE XXIX, Continued

NAME	RANK	DEPARTMENT	UNIVERSITY	PERIOD OF PARTICIPATION
Rumman, W. S.	Asst. Prof.	Civil Engr.	Michigan, U. of	Spring 1961
Tek, M. R.	Assoc. Prof.	Chem. Engr.	Michigan, U. of	Fall 1960
Van Vlack, L. H.	Prof.	Materials Engr.	Michigan, U. of	Fall 1961
Van Wylen, G. J.	Prof.,Dept. Head	Mech. Engr.	Michigan, U. of	Summer 1961
Welch, Harold J.	Asst. Prof.	Civil Engr.	Michigan, U. of	Summer 1961
Williams, G. Brymer	Prof.	Chem. Engr.	Michigan, U. of	Spring 1960
Wilson, R. C.	Asst. Prof.	Indus. Engr.	Michigan, U. of	Summer 1961
Yagle, R. A.	Asst. Prof.	Naval Arch.	Michigan, U. of	Sum.1961,Fall 1960
York, J. L.	Prof.	Chem. Engr.	Michigan, U. of	Spr.1961, Workshop 1960
Young, E. H.	Prof.	Chem. Engr.	Michigan, U. of	Sum. 1961, Workshop 1960
Sarpkaya, Turgut	Assoc. Prof.	Engr. Mech.	Nebraska, U. of	Workshop 1960
Smith, T. C.	Asst. Prof.	Engr. Mech.	Nebraska, U. of	Workshop 1960
Wolford, James C.	Assoc. Prof.	Engr. Mech.	Nebraska, U. of	Workshop 1960
Vickers, John M. F.	Assoc. Prof.	Mech. Engr.	Nebraska, U. of	Workshop 1960
Dickinson, David F.	Prof.	Nuclear Engr.	Nevada, U. of	Workshop 1961
Young, James	Assoc. Prof.	Elec. Engr.	New Mexico State U.	Workshop 1961
Houghton, Arthur V, III	Assoc. Prof.	Mech. Engr.	New Mexico, U. of	Workshop 1961
Famularo, Jack	Instructor	Chem. Engr.	New York U.	Fall 1960
Landis, Fred	Assoc. Prof.	Mech. Engr.	New York U.	Workshop 1961
Ley, B. James	Assoc. Prof.	Elec. Engr.	New York U.	Spring 1961
Seal, Philip M.	Prof.	Elec. Engr.	Norwich U.	Workshop 1960
Brown, Robert A.	Instructor	Indus. Engr.	Ohio State U.	Summer 1961
Graham, Paul F.	Assoc. Prof.	Engr. Mech.	Ohio State U.	Summer 1961
Ojalvo, Morris	Assoc. Prof.	Engr. Mech.	Ohio State U.	Summer 1961
MacAlpine, David M.	Prof.	Civil Engr.	Oklahoma State U.	Spring 61
McCollum, Paul A.	Assoc. Prof.	Elec. Engr.	Oklahoma State U.	Summer 1961
Melton, James O.	Assoc. Prof.	Indus. Engr.	Oklahoma, U. of	Summer 1961
Magnusson, P. C.	Prof.	Elec. Engr.	Oregon State College	Summer 1961
Eagleton, L. C.	Assoc. Prof.	Chem. Engr.	Pennsylvania, U. of	Workshop 1960
Schutzwohl, Victor K.	Prof.	Elec. Engr.	Pennsylvania, U. of	Workshop 1960
Schwartz, Richard F.	Asst. Prof.	Elec. Engr.	Pennsylvania, U. of	Fall 1960
Yeh, Hsuan	Prof.	Mech. Engr.	Pennsylvania, U. of	Summer 1960
Knobloch, Peter	Lecturer	Math.	Portland, U. of	Workshop 1961
Shaw, Richard P.	Asst. Prof.	Engr. Science	Pratt Inst.	Summer 1961
Greene, James H.	Assoc. Prof.	Indus. Engr.	Purdue U.	Workshop 1961
Isaacs, Gerald W.	Assoc. Prof.	Agric. Engr.	Purdue U.	Workshop 1960
Kramer, L. A.	Assoc. Prof.	Elec. Engr.	Purdue U.	Workshop 1960
Lewis, Albert D. M.	Assoc. Prof.	Civil Engr.	Purdue U.	Summer 1960
Liedl, Gerald L.	Asst. Prof.	Met. Engr.	Purdue U.	Summer 1960
Messersmith, Charles W.	Prof.	Mech. Engr.	Purdue U.	Summer 1961
Monke, E. J.	Asst. Prof.	Agric. Engr.	Purdue U.	Workshop 1961
Osborn, Henry H.	Asst. Prof.	Mech. Engr.	Purdue U.	Summer 1960
Peart, Robert M.	Instructor	Agric. Engr.	Purdue U.	Workshop 1960
Phelps, William C.,Jr.	Asst. Prof.	Met. Engr.	Purdue U.	Summer 1961
Shannon, Paul T.	Asst. Prof.	Chem. Engr.	Purdue U.	Summer 1960
Shastri, R. M.	Asst. Prof.	Mech. Engr.	Purdue U.	Summer 1961
Smith, Clyde	Asst. Prof.	Indus. Engr.	Purdue U.	Workshop 1960
Stitz, Ervin O.	Prof.	Engr. Science	Purdue U.	Workshop 1960
Toebes, Gerrit H.	Asst. Prof.	Civil Engr.	Purdue U.	Workshop 1960
Vaughn, Robert	Asst. Prof.	Chem. Engr.	Purdue U.	Workshop 1961
Young, Hewitt H.	Assoc. Prof.	Indus. Engr.	Purdue U.	Workshop 1960
Deming, Donald D.	Asst. Prof.	Indus. Engr.	Rensselaer Poly. Inst.	Summer 1961
Kobayashi, Riki	Assoc. Prof.	Chem. Engr.	Rice University	Workshop 1960
Pao, Richard H. F.	Prof.	Civil Engr.	Rose Poly. Inst.	Summer 1961
Mace, James C.	Prof.,Dept. Head	Elec. Engr.	San Jose State College	Summer 1961
Ingersoll, A. C.	Dean	School of Engr.	So. Calif., U. of	Workshop 1961
Storry, J. O.	Prof.	Elec. Engr.	So. Dak. State College	Workshop 1961
Wu, Pei-Rin	Asst. Prof.	Elec. Engr.	So. Dak. School of Mines & Metallurgy	Workshop 1961
Blose, William	Manager	Comp. Center	So. Illinois U.	Workshop 1961
Weaver, William, Jr.	Asst. Prof.	Civil Engr.	Stanford U.	Summer 1961
Zahner, John C.	Asst. Prof.	Chem. Engr.	Stanford U.	Summer 1961
Jones, Clinton	Prof.	Appl. Math.	Tenn. A&I State U.	Workshop 1961
CoVan, Jack	Prof.	Indus. Engr.	Texas A.&M. College	Summer 1960
Guthrie, William S.	Assoc. Prof.	Mech. Engr.	Texas A.&M. College	Summer 1961

TABLE XXIX, Continued

NAME	RANK	DEPARTMENT	UNIVERSITY	PERIOD OF PARTICIPATION
Amstead, B. H.	Asst. Dean	School of Engr.	Texas, U. of	Workshop 1960
Duesterhoeft, W. C.	Assoc. Prof.	Elec. Engr.	Texas, U. of	Workshop 1960
Gloyna, E. F.	Prof.	Civil Engr.	Texas, U. of	Summer 1960
Hagerty, W. W.	Dean	School of Engr.	Texas, U. of	Workshop 1960
McKetta, J. J.	Prof.,Dept. Head	Chem. Engr.	Texas, U. of	Workshop 1961
Miller, Percy H.	Asst. Prof.	Aero.Space Engr.	Texas, U. of	Workshop 1960
Morgan, Carl W.	Assoc. Prof.	Civil Engr.	Texas, U. of	Summer 1961
Pirson, S. J.	Prof.	Petrol. Engr.	Texas, U. of	Workshop 1960
Rylander, Henry G.	Assoc. Prof.	Mech. Engr.	Texas, U. of	Workshop 1960
Spital, Sidney	Prof.	Engr. Mech.	Toledo, U. of	Workshop 1960
Glen, T. M.	Asst. Prof.	Indus. Engr.	Toledo, U. of	Workshop 1961
Kirkpatrick, E. T.	Prof.,Dept. Head	Mech. Engr.	Toledo, U. of	Summer 1961
Lin, K. H.	Asst. Prof.	Chem. Engr.	Toledo, U. of	Workshop 1961
Johnson, A. I.	Assoc. Prof.	Chem. Engr.	Toronto, U. of	Summer 1961
Astill, Kenneth	Assoc. Prof.	Mech. Engr.	Tufts U.	Workshop 1961
Harris, L. Dale	Prof.,Dept. Head	Elec. Engr.	Utah, U. of	Summer 1961
Graham, Walter W.,Jr.	Prof.	Appl. Math.	Vanderbilt U.	Workshop 1961
Cheney, Lloyd T.	Prof.	Civil Engr.	Wayne State U.	Summer 1961
Hale, Harry P.	Assoc. Prof.	Mech. Engr.	Wayne State U.	Summer 1961
Sather, Roy O.	Assoc. Prof.	Elec. Engr.	Wayne State U.	Summer 1961, Workshop 1960
Szymanski, Edward	Assoc. Prof.	Elec. Engr.	Wayne State U.	Summer 1960
Tunnicliff, David	Asst. Prof.	Civil Engr.	Wayne State U.	Workshop 1961
Slonneger, Robert D.	Assoc. Prof.	Mech. Engr.	West Virginia U.	Summer 1961
Clouser, William S.	Asst. Prof.	Engr. Mech.	Wisconsin, U. of	Spring 1960
Harrison, Howard L.	Assoc. Prof.	Mech. Engr.	Wisconsin, U. of	Workshop 1960
Loper, Carl, Jr.	Asst. Prof.	Met. Engr.	Wisconsin, U. of	Workshop 1961
Wang, C. K.	Prof.	Civil Engr.	Wisconsin, U. of	Summer 1961
Zwiep, Donald	Prof.,Dept. Head	Mech. Engr.	Worcester Poly. Inst.	Workshop 1961
Kuo, Shan S.	Asst. Prof.	Civil Engr.	Yale University	Summer 1961

TABLE XXX

Faculty Participants in Project Activities
Arranged by Period of Active Participation

Spring Semester 1960

NAME	RANK	DEPARTMENT	UNIVERSITY
Brown, R. K.	Prof.	Elec. Engr.	Michigan, U. of
Enns, John H.	Prof.	Engr. Mech.	Michigan, U. of
Evans, R. V.	Asst. Prof.	Indus. Engr.	Michigan, U. of
Gyorey, G. L.	Asst. Prof.	Nuclear Engr.	Michigan, U. of
Hancock, W. M.	Prof.	Indus. Engr.	Michigan, U. of
Merte, Herman, Jr.	Asst. Prof.	Mech. Engr.	Michigan, U. of
Pehlke, Robert D.	Asst. Prof.	Met. Engr.	Michigan, U. of
Rudd, Dale F.	Asst. Prof.	Chem. Engr.	Michigan, U. of
Williams, G. Brymer	Prof.	Chem. Engr.	Michigan, U. of
Clouser, William S.	Asst. Prof.	Engr. Mech.	Wisconsin, U. of

TABLE XXX, Continued

Summer Program 1960

NAME	RANK	DEPARTMENT	UNIVERSITY
Duby, John	Assoc. Prof.	Mech. Engr.	Alberta, U. of
Au, Tung	Assoc. Prof.	Civil Engr.	Carnegie Inst. of Tech.
Liu, C. Y.	Asst. Prof.	Mech. Engr.	Carnegie Inst. of Tech.
Eitzer, Demos	Lecturer	Elec. Engr.	City U. of New York
List, Harvey L.	Asst. Prof.	Chem. Engr.	City U. of New York
White, Frank M.	Asst. Prof.	Aero. Engr.	Georgia Inst. of Tech.
Beckett, Royce E.	Assoc. Prof.	Mech. & Hydraulics	Iowa, State U. of
Carey, J. J.	Prof.	Elec. Engr.	Michigan, U. of
Eisley, J. G.	Assoc. Prof.	Aero. Engr.	Michigan, U. of
Hancock, W. H.	Prof.	Indus. Engr.	Michigan, U. of
Yeh, Hsuan	Prof.	Mech. Engr.	Pennsylvania, U. of
Liedl, Gerald L.	Asst. Prof.	Met. Engr.	Purdue U.
Lewis, Albert D. M.	Assoc. Prof.	Civil Engr.	Purdue U.
Osborn, Henry H.	Asst. Prof.	Mech. Engr.	Purdue U.
Shannon, Paul T.	Asst. Prof.	Chem. Engr.	Purdue U.
CoVan, Jack	Prof.	Indus. Engr.	Texas A. and M. College
Gloyna, E. F.	Prof.	Civil Engr.	Texas, U. of
Szymanski, Edward	Assoc. Prof.	Elec. Engr.	Wayne State U.

Workshop 1960

NAME	RANK	DEPARTMENT	UNIVERSITY
Dalla Lana, I. G.	Assoc. Prof.	Chem. Engr.	Alberta, U. of
Rodkiewicz, C. M.	Asst. Prof.	Mech. Engr.	Alberta, U. of
Quon, Donald	Assoc. Prof.	Chem. Engr.	Alberta, U. of
Youdelis, W. V.	Asst. Prof.	Min. & Metallurgy	Alberta, U. of
Lapsley, James T.,Jr.	Assoc. Prof.	Indus. Engr.	Calif., U. of (Berkeley)
Ward, Stanley H.	Assoc. Prof.	Min. Explor.	Calif., U. of (Berkeley)
Hartman, Paul	Prof.	Civil Engr.	City U. of New York
Hyman, Seymour C.	Asst. Dean	College of Engr.	City U. of New York
Patell, Minocher K.N.	Asst. Prof.	Chem. Engr.	City U. of New York
Menkes, Sherwood B.	Assoc. Prof.	Mech. Engr.	City U. of New York
Bugliarello, George	Asst. Prof.	Civil Engr.	Carnegie Inst. of Tech.
Brand, Ronald	Prof.	Mech. Engr.	Connecticut, U. of
Ahlquist, Robert	Prof.	Elec. Engr.	Detroit, U. of
Birturk, Yavuz	Instructor	Elec. Engr.	Detroit, U. of
Szczepaniak, E. A.	Asst. Prof.	Aero. Engr.	Detroit, U. of
Gorton, Charles W.	Assoc. Prof.	Mech. Engr.	Georgia Inst. of Tech.
Hoff, John	Prof.	Civil Engr.	Houston, U. of
Michaels, E. L.	Prof., Dept. Head	Elec. Engr.	Houston, U. of
Prengle, H. W.	Prof.	Chem. Engr.	Houston, U. of
Tiller, F. M.	Dean	School of Engr.	Houston, U. of
Scheck, D. C.	Asst. Prof.	Gen. Engr.	Illinois, U. of
Romanowitz, Alex	Prof., Dept. Head	Elec. Engr.	Kentucky, U. of
Snoblin, Kenneth	Prof., Head	Computer Lab.	Lawrence Inst. of Tech.
Wenzel, L. A.	Assoc. Prof.	Civil Engr.	Lehigh U.
Sword, E. C.	Asst. Prof.	Civil Engr.	Lehigh U.
Chen, A. T.	Prof.	Math.	Louisville, U. of
Brater, E. A.	Prof.	Civil Engr.	Michigan, U. of
Brownell, L. E.	Prof.	Chem. Engr.	Michigan, U. of
Farris, H. W.	Assoc. Prof.	Elec. Engr.	Michigan, U. of
Gordon, Kenneth F.	Assoc. Prof.	Chem. Engr.	Michigan, U. of
Jones, D. L.	Lecturer	Meteorology	Michigan, U. of
Kempe, L. L.	Prof.	Chem. Engr.	Michigan, U. of
Macnee, A. B.	Prof.	Elec. Engr.	Michigan, U. of
York, J. L.	Prof.	Chem. Engr.	Michigan, U. of
Young, E. H.	Prof.	Chem. Engr.	Michigan, U. of
Sarpkaya, Turgut	Assoc. Prof.	Engr. Mech.	Nebraska, U. of
Smith, T. C.	Asst. Prof.	Engr. Mech.	Nebraska, U. of
Wolford, James C.	Assoc. Prof.	Engr. Mech.	Nebraska, U. of
Vickers, John M. F.	Assoc. Prof.	Mech. Engr.	Nebraska, U. of
Seal, Philip M.	Prof.	Elec. Engr.	Norwich U.

TABLE XXX, Continued

Workshop 1960, Continued

NAME	RANK	DEPARTMENT	UNIVERSITY
Schutzwohl, Victor K.	Prof.	Elec. Engr.	Pennsylvania, U. of
Eagleton, L. C.	Assoc. Prof.	Chem. Engr.	Pennsylvania, U. of
Isaacs, Gerald W.	Assoc. Prof.	Agric. Engr.	Purdue U.
Kramer, L. A.	Assoc. Prof.	Elec. Engr.	Purdue U.
Peart, Robert M.	Instructor	Agric. Engr.	Purdue U.
Smith, Clyde	Asst. Prof.	Indus. Engr.	Purdue U.
Stitz, Ervin O.	Prof.	Engr. Science	Purdue U.
Toebes, Gerrit H.	Asst. Prof.	Civil Engr.	Purdue U.
Young, Hewitt H.	Assoc. Prof.	Indus. Engr.	Purdue U.
Kobayashi, Riki	Assoc. Prof.	Chem. Engr.	Rice University
Amstead, B. H.	Asst. Dean	School of Engr.	Texas, U. of
Duesterhoeft, W. C.	Assoc. Prof.	Elec. Engr.	Texas, U. of
Hagerty, W. W.	Dean	School of Engr.	Texas, U. of
Miller, Percy H.	Asst. Prof.	Aero. Space Engr.	Texas, U. of
Pirson, S. J.	Prof.	Pet. Engr.	Texas, U. of
Rylander, Henry G.	Assoc. Prof.	Mech. Engr.	Texas, U. of
Spital, Sidney	Prof.	Engr. Mech.	Toledo, U. of
Sather, Roy O.	Assoc. Prof.	Elec. Engr.	Wayne State U.
Harrison, Howard L.	Assoc. Prof.	Mech. Engr.	Wisconsin, U. of

Fall Semester 1960

NAME	RANK	DEPARTMENT	UNIVERSITY
Pei, Ming L.	Prof.	Civil Engr.	City U. of New York
May, George D.	Asst. Prof.	Civil Engr.	Georgia Inst. of Tech.
Balzhiser, R. E.	Asst. Prof.	Chem. Engr.	Michigan, U. of
Berkeley, Richard W.	Asst. Prof.	Indus. Engr.	Michigan, U. of
Boutwell, F. K.	Asst. Prof.	Mech. Engr.	Michigan, U. of
Carey, J. J.	Prof.	Elec. Engr.	Michigan, U. of
Eisley, J. G.	Assoc. Prof.	Aero. Engr.	Michigan, U. of
Epple, A. B.	Assoc. Prof.	Mech. Engr.	Michigan, U. of
Farris, H. W.	Assoc. Prof.	Elec. Engr.	Michigan, U. of
Harris, R. B.	Assoc. Prof.	Civil Engr.	Michigan, U. of
Johnson, Clyde	Assoc. Prof.	Indus. Engr.	Michigan, U. of
Macnee, A. B.	Prof.	Elec. Engr.	Michigan, U. of
Maugh, L. C.	Prof.	Civil Engr.	Michigan, U. of
McMullen, C. W.	Assoc. Prof.	Elec. Engr.	Michigan, U. of
Mirsky, William	Assoc. Prof.	Mech. Engr.	Michigan, U. of
Tek, M. R.	Assoc. Prof.	Chem. Engr.	Michigan, U. of
Yagle, R. A.	Asst. Prof.	Naval Arch.	Michigan, U. of
Famularo, Jack	Instructor	Chem. Engr.	New York U.
Schwartz, Richard F.	Asst. Prof.	Elec. Engr.	Pennsylvania, U. of

Spring Semester 1961

NAME	RANK	DEPARTMENT	UNIVERSITY
Brandt, G. Donald	Asst. Prof.	Civil Engr.	City U. of New York
Elrod, J. T.	Prof., Dept. Head	Indus. Engr.	Houston, U. of
Henry, R. J.	Instructor	Civil Engr.	Houston, U. of
Kittinger, William T.	Assoc. Prof.	Elec. Engr.	Houston, U. of
Akerman, J. R.	Assoc. Prof.	Mech. Engr.	Michigan, U. of
Cutrona, L. J.	Prof.	Elec. Engr.	Michigan, U. of
Gage, J. A.	Prof.	Indus. Engr.	Michigan, U. of
Graebel, W. P.	Asst. Prof.	Engr. Mech.	Michigan, U. of
McMullen, C. W.	Assoc. Prof.	Elec. Engr.	Michigan, U. of
Michelsen, Finn	Asst. Prof.	Naval Arch.	Michigan, U. of
Miller, Murray H.	Asst. Prof.	Elec. Engr.	Michigan, U. of
Pearson, J. R.	Prof.	Mech. Engr.	Michigan, U. of
Peterson, G. E.	Prof.	Elec. Engr.	Michigan, U. of
York, J. L.	Prof.	Chem. Engr.	Michigan, U. of
Rumman, W. S.	Asst. Prof.	Civil Engr.	Michigan, U. of
Ley, B. James	Assoc. Prof.	Elec. Engr.	New York U.
MacAlpine, David M.	Prof.	Civil Engr.	Oklahoma State U.

TABLE XXX, Continued

Summer Program 1961

NAME	RANK	DEPARTMENT	UNIVERSITY
Glockner, Peter	Asst. Prof.	Civil Engr.	Alberta, U. of
Kelly, Donald H.	Asst. Prof.	Elec. Engr.	Alberta, U. of
Warwaruk, Joseph	Asst. Prof.	Civil Engr.	Alberta, U. of
Paulling, J. R.	Asst. Prof.	Naval Arch.	Calif., U. of (Berkeley)
Rasof, Bernard	Assoc. Prof.	Engr. Mech.	Calif., U. of (Los Angeles)
Converse, Alvin O.	Asst. Prof.	Chem. Engr.	Carnegie Inst. of Tech.
Lowen, Gerard G.	Asst. Prof.	Mech. Engr.	City U. of New York
Pfeffer, Robert	Lecturer	Chem. Engr.	City U. of New York
Pistrang, Joseph	Asst. Prof.	Civil Engr.	City U. of New York
Aucoin, Anthony A.	Prof.	Math.	Houston, U. of
Michaels, E. L.	Prof., Dept. Head	Elec. Engr.	Houston, U. of
Michalopoulos, C. D.	Instructor	Mech. Engr.	Houston, U. of
White, Ardis	Assoc. Prof.	Civil Engr.	Houston, U. of
Anderson, George P.	Lecturer	Indus. Engr.	Illinois, U. of
Davidson, Raymond A.	Asst. Prof.	Elec. Engr.	Illinois, U. of
Shoemaker, Edward M.	Assoc. Prof.	Appl. Mech.	Illinois, U. of
Chu, Kuang-Han	Assoc. Prof.	Civil Engr.	Illinois Inst. of Tech.
Bett, Gilbert W.	Assoc. Prof.	Elec. Engr.	Massachusetts, U. of
Berry, R. M.	Prof.	Civil Engr.	Michigan, U. of
Bolt, J. A.	Prof.	Mech. Engr.	Michigan, U. of
Isakson, Gabriel	Prof.	Aero. Engr.	Michigan, U. of
Kaljian, M. J.	Asst. Prof.	Engr. Mech.	Michigan, U. of
Mosher, Raymond F.	Prof.	Elec. Engr.	Michigan, U. of
Van Wylen, G. J.	Prof., Dept. Head	Mech. Engr.	Michigan, U. of
Welch, Harold J.	Asst. Prof.	Civil Engr.	Michigan, U. of
Wilson, R. C.	Asst. Prof.	Indus. Engr.	Michigan, U. of
Yagle, R. A.	Asst. Prof.	Naval Arch.	Michigan, U. of
Young, E. H.	Prof.	Chem. Engr.	Michigan, U. of
Peatman, John B.	Asst. Prof.	Elec. Engr.	Missouri Sch. of Mines & Met
Brown, Robert A.	Instructor	Indus. Engr.	Ohio State U.
Graham, Paul F.	Assoc. Prof.	Engr. Mech.	Ohio State U.
Ojalvo, Morris	Assoc. Prof.	Engr. Mech.	Ohio State U.
McCollum, Paul A.	Assoc. Prof.	Elec. Engr.	Oklahoma State U.
Melton, James O.	Assoc. Prof.	Indus. Engr.	Oklahoma, U. of
Magnusson, P. C.	Prof.	Elec. Engr.	Oregon State College
Shaw, Richard P.	Asst. Prof.	Engr. Science	Pratt Inst.
Messersmith, Charles W.	Prof.	Mech. Engr.	Purdue U.
Phelps, W. C., Jr.	Asst. Prof.	Met. Engr.	Purdue U.
Shastri, R. M.	Asst. Prof.	Mech. Engr.	Purdue U.
Deming, Donald D.	Asst. Prof.	Indus. Engr.	Rensselaer Poly. Inst.
Pao, Richard H. F.	Prof.	Civil Engr.	Rose Poly. Inst.
Mace, James C.	Prof., Dept. Head	Elec. Engr.	San Jose State College
Weaver, William, Jr.	Asst. Prof.	Civil Engr.	Stanford U.
Zahner, John C.	Asst. Prof.	Chem. Engr.	Stanford U.
Guthrie, William S.	Assoc. Prof.	Mech. Engr.	Texas A.&M. College
Morgan, Carl W.	Assoc. Prof.	Civil Engr.	Texas, U. of
Kirkpatrick, E. T.	Prof., Dept. Head	Mech. Engr.	Toledo, U. of
Johnson, A. I.	Assoc. Prof.	Chem. Engr.	Toronto, U. of
Harris, L. Dale	Prof., Dept. Head	Elec. Engr.	Utah, U. of
Cheney, Lloyd T.	Prof.	Civil Engr.	Wayne State U.
Hale, Harry P.	Assoc. Prof.	Mech. Engr.	Wayne State U.
Sather, Roy O.	Assoc. Prof.	Elec. Engr.	Wayne State U.
Slonneger, Robert D.	Assoc. Prof.	Mech. Engr.	West Virginia U.
Wang, C. K.	Prof.	Civil Engr.	Wisconsin, U. of
Kuo, Shan S.	Asst. Prof.	Civil Engr.	Yale U.

TABLE XXX, Continued

Workshop 1961

NAME	RANK	DEPARTMENT	UNIVERSITY
Prawel, Sherwood, Jr.	Asst. Prof.	Engr.	Buffalo, U. of
Rollins, Carl	Instructor	Elec. Engr.	Buffalo, U. of
Hazlett, Thomas H.	Prof.	Indus. Engr.	Calif., U. of (Berkeley)
McHugh, Edward	Prof.	Mech. Engr.	Clarkson College of Tech.
Vrana, Norman	Assoc. Prof.	Elec. Engr.	Cornell U.
Heckbert, Albert I.	Assoc. Prof.	Elec. Engr.	Dartmouth College
Howerton, Murlin T.	Prof.	Chem. Engr.	Denver, U. of
Jessup, Bob A.	Prof., Dept. Head	Elec. Engr.	Detroit Inst. of Tech.
Woodworth, Forrest M.	Asst. Prof.	Engr. Graphics	Detroit, U. of
Uhl, Vincent W.	Prof.	Chem. Engr.	Drexel Inst. of Tech.
Bailey, Albert D.	Prof.	Elec. Engr.	Illinois, U. of
Boctor, Magdy L.	Instructor	Engr. Graphics	Iowa State U.
Trummel, J. Merle	Assoc. Prof.	Mech. Engr.	Iowa, State U. of
Quinn, Cleo J.	Instructor	Mech. Engr.	Indiana Tech. College
Graham, Peter J.	Asst. Prof.	Elec. Engr.	Kentucky, U. of
Herbich, John B.	Assoc. Prof.	Civil Engr.	Lehigh U.
Manning, Thomas A.	Instructor	Engr. Mech.	Louisiana State U.
Lindsey, E. E.	Prof.	Chem. Engr.	Massachusetts, U. of
Berkeley, Richard W.	Asst. Prof.	Indus. Engr.	Michigan, U. of
Bigelow, Wilbur C.	Prof.	Sci. Engr.	Michigan, U. of
Heimbach, C. L.	Instructor	Civil Engr.	Michigan, U. of
Young, James	Assoc. Prof.	Elec. Engr.	New Mexico State U.
Houghton, Arthur V., III	Assoc. Prof.	Mech. Engr.	New Mexico, U. of
Landis, Fred	Assoc. Prof.	Mech. Engr.	New York U.
Dickinson, David F.	Prof.	Nuclear Engr.	Nevada, U. of
Knobloch, Peter	Lecturer	Math.	Portland, U. of
Greene, James H.	Assoc. Prof.	Indus. Engr.	Purdue U.
Monke, E. J.	Asst. Prof.	Agric. Engr.	Purdue U.
Vaughn, Robert	Asst. Prof.	Chem. Engr.	Purdue U.
Ingersoll, A. C.	Dean	School of Engr.	Southern Calif., U. of
Storry, J. O.	Prof.	Elec. Engr.	So. Dak. State College
Wu, Pei-Rin	Asst. Prof.	Elec. Engr.	So. Dak. School of Mines & Technology
Blose, William	Manager	Comp. Center	Southern Illinois U.
Jones, Clinton	Prof.	Appl. Math.	Tenn. A.&I. State U.
McKetta, J. J.	Prof., Dept. Head	Chem. Engr.	Texas, U. of
Glen, T. M.	Asst. Prof.	Indus. Engr.	Toledo, U. of
Lin, K. H.	Asst. Prof.	Chem. Engr.	Toledo, U. of
Astill, Kenneth	Assoc. Prof.	Mech. Engr.	Tufts U.
Graham, Walter W., Jr.	Prof.	Appl. Math.	Vanderbilt U.
Tunnicliff, David	Asst. Prof.	Civil Engr.	Wayne State U.
Loper, Carl, Jr.	Asst. Prof.	Met. Engr.	Wisconsin, U. of
Zwiep, Donald	Prof.	Mech. Engr.	Worcester Poly. Inst.

Fall Semester 1961

NAME	RANK	DEPARTMENT	UNIVERSITY
Eickberger, L. C.	Asst. Prof.	Mech. Engr.	Houston, U. of
Howe, J. W.	Prof., Dept. Head	Mech. & Hydraulics	Iowa, State U. of
Bigelow, W. C.	Prof.	Sci. Engr.	Michigan, U. of
Brownell, L. E.	Prof.	Chem. Engr.	Michigan, U. of
Churchill, S. W.	Prof., Dept. Head	Chem. Engr.	Michigan, U. of
Clark, John A.	Prof.	Mech. Engr.	Michigan, U. of
Debler, Walter R.	Assoc. Prof.	Engr. Mech.	Michigan, U. of
Dingle, A. N.	Assoc. Prof.	Meteorology	Michigan, U. of
Kazda, L. F.	Prof.	Elec. Engr.	Michigan, U. of
Van Vlack, L. H.	Prof.	Materials Engr.	Michigan, U. of

TABLE XXXIa

Master Mailing List of Colleges and Universities

a. Engineering Colleges in the United States and Canada

Air Force Inst. of Technology
Akron, U. of
Alabama, U. of
Alaska, U. of
Alfred U.
Antioch College
Arizona State U.
Arizona, U. of
Arkansas, U. of
Auburn U.
Bradley U.
Brigham Young U.
Brooklyn, Polytech. Inst. of
Brown U.
Bucknell U.
Buffalo, U. of
California Inst. of Tech.
Calif., U. of (Berkeley)
Calif., U. of (Davis)
Calif., U. of (Los Angeles)
Calif., U. of (Santa Barbara)
Carnegie Inst. of Technology
Case Inst. of Technology
Catholic U. of America
Chattanooga, U. of
Cincinnati, U. of
Citadel, The
Clarkson College of Technology
Clemson College
Colorado School of Mines
Colorado State U.
Colorado, U. of
Columbia U.
Connecticut, U. of
Cooper Union
Cornell U.
Dartmouth College
Dayton, U. of
Delaware, U. of
Denver, U. of
Detroit Inst. of Technology
Detroit, U. of
Drexel Inst. of Technology
Duke U.
Farleigh Dickinson U.
Fenn College
Florida, U. of
George Washington U.
Georgia Inst. of Technology
Georgia, U. of
Hawaii, U. of
Harvard U.
Houston, U. of
Howard U.
Idaho, U. of
Illinois Inst. of Technology
Illinois, U. of
Indiana Technical College
Iowa State U.
Iowa, State U. of
Johns Hopkins U.
Kansas State U.
Kansas, U. of
Kentucky, U. of
Lafayette College
Lamar State College of Tech.
Lawrence Inst. of Technology
Lehigh U.
Louisiana Polytechnic Inst.
Louisiana State U.
Louisville, U. of
Lowell Technological Inst.
Maine, U. of
Miami, U. of
Manhattan College
Marquette U.
Maryland, U. of
Massachusetts Inst. of Tech.
Massachusetts, U. of
Michigan College of Mining and Technology
Michigan State U.
Michigan, U. of
Minnesota, U. of
Mississippi State U.
Missouri School of Mines and Metallurgy
Missouri, U. of
Mississippi, U. of
Montana School of Mines
Montana State College
Nebraska, U. of
Nevada, U. of
Newark College of Engr.
New Hampshire, U. of
New Mexico State U.
New Mexico, U. of
New York U.
New York, City U. of
North Carolina State U.
North Carolina, A.&T. Coll. of
North Dakota State U.
North Dakota, U. of
Northeastern U.
Northwestern U.
Norwich U.
Notre Dame, U. of
Ohio Northern U.
Ohio State U.
Ohio U.
Oklahoma State U.
Oklahoma, U. of
Oregon State U.
Pennsylvania State U.
Pennsylvania, U. of
Pittsburgh, U. of
Portland, U. of
Pratt Institute
Princeton U.
Puerto Rico, U. of
Purdue U.
Rensselaer Polytech. Inst.
Rhode Island, U. of
Rice U.
Rochester, U. of
Rose Polytechnic Inst.
Rutgers U.
St. Louis U.
San Jose State College
Santa Clara, U. of
Seattle U.
South Carolina, U. of
Southern California, U. of
So. Dakota School of Mines and Technology
So. Dakota State College
Southern Methodist U.
Southwestern Louisiana, U. of
Stanford U.
Stevens Inst. of Technology
Swarthmore College
Syracuse U.
Tennessee A.&I. State U.
Tennessee, U. of
Texas, A.&M. College of
Texas College of Arts & Industries
Texas Technological College
Texas Western College
Texas, U. of
Toledo, U. of
Trinity College
Tulane U.
Tufts U.
Tulsa, U. of
Union College and U.
U.S. Naval Postgraduate School
Utah State U.
Utah, U. of
Valparaiso U.
Vanderbilt U.
Vermont, U. of
Villanova U.
Virginia Military Inst.
Virginia Polytechnic Inst.
Virginia, U. of
Washington U.
Washington State U.
Washington, U. of
Wayne State U.
Webb Inst. of Naval Arch.
West Virginia U.
Wichita, U. of
Wisconsin, U. of
Worcester Polytechnic Inst.
Wyoming, U. of
Yale U.
Youngstown U.

Canadian Schools

Alberta, U. of
British Columbia, U. of
Ecole Polytechnique
Laval U.
Manitoba, U. of
McGill U.
New Brunswick, U. of
Nova Scotia Technical College
Queens U.
Saskatchewan, U. of
Toronto, U. of

TABLE XXXIb

Other Schools and Universities in the United States and Canada

Alameda State College	Hamilton College	St. Johns U.
Arlington State College	Harvey Mudd College	St. Marys College
Baylor U.	Los Angeles State College	St. Thomas, U. of
Bowling Green State U.	Merrimack College	Tennessee Polytech. Inst.
Calif. State Polytech. College	Monterey Peninsula College	Texas Christian U.
Carleton U.	Montreal, U. of	Trenton Junior College
Carleton College	Mt. San Antonio College	Tri-State College
Carroll College	New York, State U. of	Tuskegee Institute
Chicago, U. of	North Carolina, U. of	U.S. Army Command and Gen. Staff College
Christian Brothers College	Northrop Inst. of Technology	U.S. Coast Guard Academy
Davidson College	Oakland City College	U.S. Military Academy
Daytona Beach Jr. College	Ohio Wesleyan U.	U.S. Naval Academy
Essex College	Orange Coast College	Western Michigan U.
Florida State U.	Rochester Inst. of Technology	Western New England College
Fullerton Jr. College	San Diego State College	Wichita, U. of
General Motors Inst.	San Francisco State College	
Grinnell College	St. Bonaventure U.	

TABLE XXXIc

Foreign Universities

Adelaide, U. of - Austrailia	Technische Hochschule Munchen -Germany
Al-Hikma U. of Baghdad - Iraq	Norges Tekniske Hogskile - Norway
Cambridge University	Royal College of Adv. Tech.-England
Chile, U. of	U. Tecnica Federico Santa Maria - Chile
Conception, U. of - Chile	Technion Israel Inst. of Technology
Denmark, The Technical U. of	Universidad Central de Venezuela
Imperial College of Science and Technology - England	U. College of the West Indies
Inst. Tech. de Aeron San Jose Dos Campos - Brazil	Weizmann Inst. of Science - Israel
Kyoto U. - Japan	
Loughborough College of Technology - England	
Melbourne, U. of - Australia	
Universidad Nacional de Mexico	

TABLE XXXII

Example Engineering Problems Prepared by Project Participants
Arranged by Engineering Discipline

Problems in Aeronautical Engineering

No.	Title	Author	Source*
28	Lift Distribution of a Finite Wing	Hsuan Yeh	1st A.R.
29	Bending Stresses in a Multi-Flange Aircraft Structure	F. M. White	1st A.R.
30	Numerical Solutions of the Blasius Differential Equation for the Laminar Boundary Layer on a Flat Plate	F. M. White	1st A.R.
31	Steady State Flow in a Long Tube Connected by Flare Fittings to Large Entrance and Exit Pipes	F. M. White	1st A.R.
39	A Problem in Orbital Flight Mechanics	J. G. Eisley	1st A.R.
105	A Third-Order Control System	R. M. Howe	Final
106	A Multi-Loop Aircraft Control Problem	R. M. Howe	Final
107	Solutions of the Linearized Longitudinal Flight Equations	R. M. Howe	Final
108	Solutions of the Linearized Lateral Flight Equations	R. M. Howe	Final
109	Two-Dimensional Re-Entry Trajectories for Lifting Vehicles	R. M. Howe	Final
110	Free Vibration Characteristics of a Uniform Cantilever Beam with Elastic Root Restraint	G. Isakson	Final
111	Re-Entry Path of a Flight Vehicle	G. Isakson and J. L. Lemay	Final

Problems in Chemical Engineering

No.	Title	Author	Source*
1	Temperature Distribution in Conducting Solid	D. F. Rudd	1st A.R.
6	Stage-Wise Extraction of Sugar from Beets	P. B. Lederman	1st A.R.
7	Computation of Fugacity Coefficients from Compressibility Factors	K. H. Coats	1st A.R.
12	Temperature and Composition Profiles in a Catalytic Bed Chemical Reactor	K. F. Gordon	1st A.R.
18	Design of a Minimum Cost Air Cooled Heat Exchanger	B. Carnahan	1st A.R.
19	Determination of Terminal Settling Velocity of a Spherical Particle in a Fluid	H. L. List	1st A.R.
20	Pressure Drop and Expansion in Fixed and Fluidized Beds	H. L. List	1st A.R.
41	Calculation of Vapor and Liquid Fugacity for Fluids Obeying the Martin-Hou Equation of State	P. T. Shannon	1st A.R.
44	Transient Behavior of Batch Reactor Systems	P. T. Shannon	1st A.R.
52	Solution of a Boundary Value Problem Using an Initial Value Technique - Temperature Profile in a Circular Transverse Fin	R. Pfeffer	2nd A.R.
54	Velocity Profiles for Flow in Smooth Pipes	R. Pfeffer	2nd A.R.
112	Temperatures and Heat Flux in a Radiant Thermal Circuit	W. C. Phelps	Final
113	Minimum Cost of Reactor Operation	A. I. Johnson	Final
114	Adiabatic Reactor	R. E. Balzhiser	Final
115	Successive and Simultaneous First-Order Chemical Reactions	R. N. Pease	Final
116	Pyrolysis of Ethane in a Tubular Reactor	J. O. Wilkes	Final
117	Adiabatic Flame Temperature for Carbon Monoxide Oxidation	J. J. Martin and B. Carnahan	Final
118	Vapor-Liquid Equilibrium	R. Bonnecaze	Final
119	Solvent Allocation in Multi-Stage Cross-Current Extraction	A. O. Converse	Final
120	Dynamic Heat Exchange	J. Famularo	Final
121	Use of Computers in an Undergraduate Chemical Engineering Design Course	D. F. Rudd	Final
122	Economic Design of a Condenser	D. E. Briggs	Final

* First Annual, Second Annual or Final Reports, or available on Microfilm.

TABLE XXXII, Continued

Problems in Chemical Engineering, Continued

No.	Title	Author	Source*
M49	Multiple Regression	A. O. Converse	Micro
M50	Liquid Level Control System	R. N. Pease	Micro
M51	Temperature Profile in a Longitudinal Fin Using the Analog Computer	R. Pfeffer	Micro
M52	Number of Theoretical Plates in a Multi-Component Distillation Column	R. Pfeffer	Micro
M53	Approach to Steady State of an Othmer Still	A. I. Johnson	Micro
M54	Storage of Natural Gas in Aquifers	M. R. Tek	Micro
M55	Determination of Reflux Ratio by McCabe-Thiele Method	J. C. Zahner	Micro

Problems in Civil Engineering

No.	Title	Author	Source*
8	Preliminary Design and Economic Study for a Dam Project - Parts 1-6	V. L. Streeter	1st A.R.
9	Analysis of a Quadrilateral	H. J. Welch	1st A.R.
10	Response Spectrum for Elasto-Plastic Structures	G. V. Berg	1st A.R.
21	Reactions of a Statically Indeterminate Truss	A. D. M. Lewis	1st A.R.
22	Solution of Secant Formula for Eccentrically Loaded Columns	A. D. M. Lewis	1st A.R.
23	Table of Allowable Column Stresses	A. D. M. Lewis	1st A.R.
27	Moments and Deflections of a Simple Beam	Tung Au	1st A.R.
45	Oxygen Depletion in Streams	E. F. Gloyna	1st A.R.
48	Influence Diagram for Thrust on an Unsymmetrical Two-Hinged Arch	C. K. Wang	2nd A.R.
49	Moment Distribution Table for Continuous Beams	C. K. Wang	2nd A.R.
50	Moment Distribution Analysis of Rigid Frames Without Sidesway	C. K. Wang	2nd A.R.
76	Use of the Computer as a Teaching Machine for Plane Analytic Geometry	H. J. Welch	Final
77	Optimum Regulation of a Reservoir for Power Production	J. W. Howe	Final
78	Economical Size of Canal-Feeding Hydro-Power Plants	J. W. Howe	Final
79	Most Probable Number Method for Determining Bacterial Populations	L. L. Kempe	Final
80	Iteration of Sum of Principal Stress at Interior Points of Plane Rings	W. Weaver, Jr.	Final
81	Elastic Buckling Loads for Columns of Non-Uniform Cross-Section	K. H. Chu	Final
82	A MAD Program for Truss Analysis	K. H. Chu	Final
83	Stiffness Factor for a Flat Slab Column	R. B. Harris	Final
84	Vibration of Beams on Spring Supports	S. S. Kuo	Final
M1	The Design of Column Grillages	G. D. Brandt	Micro
M2	Bending Moments and Deflections of Statically Determinate Beams by Finite Differences	G. D. Brandt	Micro
M3	The Design of Crane Runway Girders	G. D. Brandt	Micro
M4	The Calculation of Area Properties from Coordinates	G. D. Brandt	Micro
M5	Latitude by Time-Altitude Observations of Polaris	G. D. Brandt	Micro
M6	Latitude by Circum-Meridian Altitudes of the Sun	G. D. Brandt	Micro
M7	Azimuth Computation from Polaris at any Hour Angle	G. D. Brandt	Micro
M8	Single Altitude Solar Azimuth	G. D. Brandt	Micro
M9	Infinite Series Nature of Moment Distribution	L. T. Cheney	Micro
M10	Lateral Load Analysis of Plane Rigid Frames by Successive Approximations	P. Glockner	Micro
M11	Fiber Stresses in a Curved Beam of Rectangular Cross-Section	P. F. Graham	Micro
M12	Reduction of Rectangular Strain Gauge Rosette Data	P. F. Graham	Micro
M13	Deflection Influence Line for Simple Beams	D. M. MacAlpine	Micro
M14	Buckling Loads of Pin-Ended Non-Uniform Columns in the Inelastic Range	M. Ojalvo	Micro
M15	Calculation of Backwater Curve for Flow in a Wide Rectangular Open Channel	R. H. F. Pao	Micro
M16	Truss Deflections by Virtual Work	M. L. Pei	Micro
M17	Shear and Moment Diagrams	J. Pistrang	Micro
M18	Determination of True Dihedral Angle	G. A. Stickels	Micro
M19	Buckling Loads for Columns	J. Warwaruk	Micro

* First Annual, Second Annual or Final Reports, or available on Microfilm.

TABLE XXXII, Continued

Problems in Electrical Engineering

No.	Title	Author	Source*
11	Analysis of a Class C Amplifier	R. K. Brown	1st A.R.
24	The Root Locus of a Transfer Function	D. Eitzer	1st A.R.
25	Amplitude and Phase Response of a Transfer Function	D. Eitzer	1st A.R.
26	The Series Magnetic Circuit with an Air Gap	D. Eitzer	1st A.R.
34	The Solution of Differential Equations by Numerical Methods	D. Eitzer	1st A.R.
35	Luminous Efficiency of a Black Body Radiator	E. Szymanski	1st A.R.
36	Determination of the Unnecessary Elements in a Switching Circuit	E. Szymanski	1st A.R.
37	Potential Distribution in a Two-Dimensional Field	E. Szymanski	1st A.R.
40	Analysis of Non-Sinusoidal Voltage Wave Forms	E. Szymanski	1st A.R.
42	The Solution of Non-Linear Electric Circuits on the Analog Computer	D. Eitzer	1st A.R.
43	Transient Analysis of an R-L-C Circuit with Sinusoidal Excitation	E. Szymanski	1st A.R.
46	Log-Magnitude and Phase Plots of Coupling Networks	B. J. Ley	2nd A.R.
53	A Mathematical Model of an Electromagnetic Transducer	P. A. McCollum	2nd A.R.
85	Determination of the RMS Value of Currents by Direct Integration and from the Fourier Coefficients	B. J. Ley	Final
86	Evaluation of the Fourier Coefficients by the Digital and Analog Computer	B. J. Ley	Final
87	The Evaluation of the Fourier Integral and the Plotting of the Frequency Spectrum	B. J. Ley	Final
M20	Determination of System Frequency Response from Experimental Response to a Unit Step Input	G. W. Bett	Micro
M21	Determination of the Stability of a Linear System by Means of Routh's Criterion	G. W. Bett	Micro
M22	Polynomial Root Solving by Lin's Method	G. W. Bett	Micro
M23	AC Steady State Solution of a Lossy Transmission Line for Various Points Along the Line	R. A. Davidson	Micro
M24	Non-Linear Feedback System of Fourth Order	L. D. Harris	Micro
M25	Fourier Analysis of a Complex Wave	D. H. Kelly	Micro
M26	Solution of a Generalized Passive Ladder Network	D. H. Kelly	Micro
M27	Shock Response of Non-Linear Systems	S. S. Kuo	Micro
M28	Two-Dimensional Field Problem	B. J. Ley	Micro
M29	Analog and Digital Solution of a Two-Degree of Freedom System	B. J. Ley	Micro
M30	Analog Computer Solution of Two One-Degree of Freedom Systems	B. J. Ley	Micro
M31	Bode Plot of an Automatic Speed Regulator	B. J. Ley	Micro
M32	Falling Body Problem	B. J. Ley	Micro
M33	Random Number Area Calculation	B. J. Ley	Micro
M34	Course Grades	B. J. Ley	Micro
M35	Electron Trajectories in an Inverted Magnetron	R. J. Lomax	Micro
M36	A Plot of Equipotential Points Surrounding a System of Charges	J. C. Mace	Micro
M37	Step by Step Solution of a Ladder Network	J. C. Mace	Micro
M38	Evaluation of Ratio of Polynomials	A. B. Macnee	Micro
M39	Symmetrical Component Resolution	P. C. Magnusson	Micro
M40	Properties of an Electrical Transmission Line	P. C. Magnusson	Micro
M41	Location of Equilibrium Angles for 3-Synchronous Machine Systems	P. C. Magnusson	Micro
M42	High Frequency Response of a Shunt Compensated Amplifier	C. W. McMullen	Micro
M43	Complex Plane Loci of Transfer Functions	E. L. Michaels	Micro
M44	Approximation of Any Transfer Function by a Function Realizable with an RC Network	J. B. Peatman	Micro
M45	Analysis of a Feedback Control System	R. O. Sather	Micro
M46	Electric Field Intensity Problem	R. F. Schwartz	Micro

* First Annual, Second Annual or Final Reports, or available on Microfilm.

TABLE XXXII, Continued

Problems in Engineering Mechanics

No.	Title	Author	Source*
55	Kinematics and Dynamics of Slider Crank Chain	G. G. Lowen	2nd A.R.
97	Numerical Solution of the Harmonic and Biharmonic Equation	W. P. Graebel	Final
98	The Joukowski Airfoil	W. P. Graebel	Final
99	Principal Axes of a Second Order Tensor	W. P. Graebel	Final
M47	Generation and Maintenance by Winds of Currents in the Great Lakes	D. L. Jones	Micro
M48	Rotation of Axes for a Stress Tensor	R. P. Shaw	Micro

Problems in Industrial Engineering

No.	Title	Author	Source*
38	Industrial Data Processing	W. H. Hancock	1st A.R.
51	Paired Data "t" Test (Statistical Significance Test)	J. T. Elrod	2nd A.R.
57	A Queueing Dynamics Problem	R. A. Brown	Final
58	Optimizing Machine Loading	E. T. Kirkpatrick	Final
59	Regression Analysis	J. T. Elrod	Final
60	Critical Path Scheduling	R. C. Wilson	Final
61	Minimum Path Through a Network	R. C. Wilson	Final
62	Engineering Economy	J. Pistrang	Final
63	Traffic Count Analysis	J. Pistrang	Final
64	Machine Utilization	D. D. Deming	Final

Problems in Mechanical Engineering

No.	Title	Author	Source*
15	Compressibility Factors of Gases From the Beattie-Bridgeman Equation of State	H. Merte	1st A.R.
32	Minimum-Weight Rectangular Radiant Cooling Fin	C. Y. Liu	1st A.R.
33	Dynamic Loading on a Uniform Beam	R. C. Beckett	1st A.R.
56	An Analytical Method of Determining the Location of a Normal Shock Wave in Nozzle Flow of an Ideal Gas	C. D. Michalopoulos	2nd A.R.
65	Isentropic Process for Ideal Gas with Variable Specific Heat	R. D. Slonneger	Final
66	Compressibility Factors Using the Beattie-Bridgeman Equation of State	R. E. Sonntag	Final
67	The Effect of Pressure and Propellant Ratio on Hydrogen-Oxygen Rocket Performance	R. E. Sonntag	Final
68	Determination of the Composition of the Products of Combustion	R. M. Shastri	Final
69	Flame Temperature for Combustion of Air and Methane	R. E. Sonntag	Final
70	Transient Temperature Calculations for a Jacketed Mixing Kettle	E. T. Kirkpatrick	Final
71	Surge Systems Oscillations	H. P. Hale	Final
72	Analog Analysis of a Sinusoidally Excited Spring-Mass-Dashpot System	C. M. Messersmith	Final
73	Bevel Gear Speed Reducer Force Analysis	J. R. Pearson	Final
74	Cam Design Proposal Analysis	J. R. Pearson	Final
75	Use of the Electronic Differential Analyzer to Study the Dynamics of Machinery		Final

* First Annual, Second Annual or Final Reports, or available on Microfilm.

TABLE XXXII, Continued

Problems in Metallurgical, Materials, and Mining Engineering

No.	Title	Author	Source*
2	Scavenging of Dissolved Gas from Molten Metal	R. D. Pehlke	1st A.R.
3	Cooling of A Liquid-Metal Transport Ladle	R. D. Pehlke	1st A.R.
4	Enthalpies of Some Metallic Elements at Regular Temperature Intervals	R. D. Pehlke	1st A.R.
5	Concentration of Carbon, Hydrogen and Oxygen in Helium-Cooled Graphite Nuclear Reactor	D. V. Ragone and J. M. Dealy	1st A.R.
13	Metallographic Determination of Size Distribution of Nodules	M. J. Sinnott	1st A.R.
14	Nucleation and Growth of Solid Phases	M. J. Sinnott	1st A.R.
16	Expansion of a Gas in a Tank	R. E. Balzhiser	1st A.R.
17	Ito's Method for Indexing Powder Patterns	G. L. Liedl	1st A.R.
47	Digital Computer Simulation of a Bottom-Pouring Ladle	R. D. Pehlke	2nd A.R.
88	Furnace Efficiency as a Function of Stack Gas Temperature	B. Carnahan	Final
89	Mass or Heat Transfer by Diffusion	M. J. Sinnott	Final
90	Predicting the Scrap Requirement for the Oxygen-Steel Converting Process	R. D. Pehlke	Final
91	Precision Lattice Parameter Determination for a Cubic Material	J. V. Gluck	Final
92	Ionic Crystal Structures	L. H. Van Vlack	Final
93	Unsteady Heat Conduction in a Solidifying Alloy	J. R. Street and J. O. Wilkes	Final
94	Cooling of Pig Iron in Transfer Ladle	R. D. Pehlke	Final
95	Digital Computer Analysis of Heat Flow and Temperature Distribution Around a Copper Converter Tuyere	R. D. Pehlke	Final
96	Digital Computer Analysis of Galvanic Cell Data	R. D. Pehlke and K. J. Guion	Final

Problems in Naval Architecture

No.	Title	Author	Source*
100	Tank Volume and Centroid	R. A. Yagle	Final
101	Calculation for the Curves of Form	R. A. Yagle	Final
102	Program to Compute and Plot Curves of Form	J. J. Rodnite	Final
103	Calculation of the Drafts Fore and Aft of a Damaged Ship	R. A. Yagle and J. R. Paulling, Jr.	Final
104	Floodable Length Calculations	R. A. Yagle and J. R. Paulling, Jr.	Final

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