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ABSTRACT

At the present time, nine of the fourteen provincially-assisted universities in Ontario, Canada offer programs leading to degrees in the field of engineering, and two others offer 2-year curricula in the field. This document presents a study of engineering education in Ontario, covering both the undergraduate and graduate fields, and examining student flows, curricula, research, staff, facilities and costs with a perspective developed from an analysis of the career patterns of engineering graduates. The present report of the study is designed to be a tentative master plan that might be used as a guide for rational growth of engineering education during the coming decade. It endeavors to provide for the highest quality, the best use of resources, an opportunity for innovation, and maximum freedom of choice for students in engineering. (HS)

ED 067048

A report to the

Committee of Presidents of Universities of Ontario

Comité des Présidents d'Université de l'Ontario

Ring of Iron

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The opinions expressed in this report are those of the study group, and do not necessarily coincide with the views of the Committee of Presidents of Universities of Ontario.

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COMMITTEE OF
PRESIDENTS OF UNIVERSITIES
OF ONTARIO

COMITÉ DES
PRÉSIDENTS D'UNIVERSITÉ
DE L'ONTARIO

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STUDY OF ENGINEERING EDUCATION IN ONTARIO

Dr. D. C. Williams,
Chairman,
Committee of Presidents of
Universities of Ontario,
c/o University of Western Ontario,
London, Ontario.

Dear Dr. Williams,

I hereby submit to you the report entitled "Ring of Iron", a Study of Engineering Education in Ontario, November, 1970. It is my hope that this document will make a contribution to the evolution of an efficient "system" of engineering education in this province during the present decade.

Yours sincerely,

Philip A. Lapp

Philip A. Lapp,
Director.

PAL:jb
Enc:

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PREFACE

Ontario is a province of more than 7,500,000 people with fourteen provincially-assisted universities. Nine of these institutions grant degrees in engineering, while two of the others offer the first two years of engineering, and both have indicated a desire to add the remaining two years in order to be able to award engineering degrees. The remaining three institutions do not provide any instruction in engineering. Prior to the mid-1950s, there were only two engineering schools in the province, and the increase in the number of schools has occurred over the past fifteen years at a pace that has precluded any system planning. As we move into the 1970s the need for rationalization has become critical.

At the request of the Committee of Presidents of Universities of Ontario (CPUO), the Committee of Ontario Deans of Engineering (CODE) developed a proposal to conduct a study of engineering education in Ontario. It was to cover both the undergraduate and graduate fields, and examine student flows, curricula, research, staff, facilities and costs with a perspective developed from an analysis of the career patterns of engineering graduates. The objective was to create a master plan which might be used as a guide for rational growth of engineering education during this decade. Such a plan should endeavour to provide for the highest attainable quality, the best use of resources, an opportunity for innovation, and maximum freedom of choice for students. A twelfth engineering school, the Royal Military College of Canada, although funded entirely by the federal government, was included in certain aspects of the study.

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Work commenced in October of 1969, with the appointment of a full-time director under the guidance of a liaison committee representing CPUO and CODE. Next, a study group was formed. Two of the group are engineers, one from industry with an aerospace engineering background (the director), and the other with an academic and research background in chemical engineering — the former Dean of Engineering at McMaster University. Between them, they cover a broad spectrum of engineering and scientific disciplines. In order to contribute a balancing viewpoint from another profession, the third member of the group is a non-engineer, with a background of university administration: the former president of the University of New Brunswick.

In consultation with the engineering schools, a questionnaire was developed, calling for the generation of data from each university. In addition, a brief was received from the Association of Professional Engineers of Ontario. These submissions formed the basis upon which many of the recommendations have been developed. The study group travelled extensively — 132 organizations were visited in Canada, the United States and Europe, and informal hearings were held at each Ontario university, when members of the study group spoke with students, faculty and staff. More than three hundred students were involved in these discussions, and a separate student questionnaire provided a variety of viewpoints from several hundred more.

The study group is indebted to those who contributed so much time and effort to this study. They are too numerous to mention individually, but many of them will recognize passages in this report. We would ask them to treat this discovery as conveying a message of thanks. Nevertheless, the study group accepts full responsibility for the way in which the information is presented and for the specific recommendations. We wish to acknowledge the contribution of the staff at CPUO, who gave countless hours to the compilation and processing of data, and convey our special thanks to the Committee of Presidents of Universities of Ontario for publishing the three auxiliary documents containing our source material. Also, we wish to acknowledge our gratitude to the study group secretary, Mrs. Joan Barnes, who put in long and hard hours of work in the preparation of the manuscript. Our thanks are also due to Mrs. Barbara Brougham, who edited the report and oversaw its production, and to Miss Valda Steet, who did the art work.

The director would like to convey his deep appreciation for the warm spirit and friendly rapport that has developed within the study group. In spite of diverse backgrounds and personalities, its members reached accord on every major issue — there is no minority report. The sensitivity, sincerity and enthusiasm of Dr. Hodgins and the perception and Maritime wit of Dr. Mackay made it a pleasure for the director to work with these two gentlemen.

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GRANDSONS OF MARTHA

"It is their care, in all the ages, to take
the buffet and cushion the shock.
It is their care that the gear engages —
it is their care that the switches lock. . . ."
—*Rudyard Kipling,*
"The Sons of Martha"

This is to be a report about our most precious resource: young people. In particular, it is a report about young people just entering a crucial phase in their lives, as they complete secondary school, make firm career decisions, and set their courses for professional education. In the development of this study, we talked with many such young people; we have argued, laughed, agonized and agreed with them, we have listened to them and learned from them. We have discovered that the engineering student in Ontario is committed, cooperative and constructive. He does not want to burn down the classroom, but is eager to assist in improving what goes on inside it. He is developing a social consciousness far more rapidly than most of his teachers, and believes that engineering education should mirror this awakening.

For the chronology of this report, it seemed appropriate to begin with the day of graduation from secondary school — in June of 1970. What a vastly more perplexing day this was than the corresponding day in 1950. Now, almost all of the environment is in the throes of rapid change — society, technology and education itself; a workable set of value judgments is not easy to devise in the 1970s. To us it seems important, at the outset, to try to sketch some of the background against which these value judgments are made, and against which expectations and aspirations are developed. First, we need a student for whom we can provide a fairly clear personality and aptitude description; we shall call him/her Jean (French- or Anglo-Canadian).

Jean is 18 years old and comes from an average Ontario family. He likes to work with his hands, and though not intensely materialistic, has a pragmatic outlook on life. Possessed of a natural aptitude for mathematics and science, he graduated from high school with averages of over 70% in those subjects. He has found little difficutly in deciding between science-engineering and arts-social sciences. There was the aptitude in mathematics and sciences — everyone had underscored that as a necessary attribute. Then, there was the lack of any real interest in high school English courses, and a lack of ability in foreign language studies.

The decision between science and technology was more difficult. In high school he knew more about science. because few teachers were engineers and there was little technology in the curriculum, and many of those in guidance tended to describe engineering as it existed in the 1940s. To remedy this situation, the Committee of Ontario Deans of Engineering has commissioned the preparation of a series of audio-visual presentations for the use of Ontario high schools in 1971 — too late for Jean. But our student's desire to see his ideas translated into something tangible and practicable is a strong one, and so the motivation to apply science to a practical end finally swung his decision in the direction of engineering.

One need not belabour the social implications of engineering in the final third of the twentieth century. It is awesome to contemplate its potential for good and evil which has, within a single generation, revolutionized transportation and communication while creating the threat of instant oblivion. Ontario society in the 1970s is showing all the stresses produced by too rapid economic expansion and too little socio-economic planning — too much emulation and too little innovation. After a brilliant performance throughout the years of war, Ontario's technology is now strangely unadventurous, as risk capital outweighs risk thinking, and industry takes most of its cues from beyond our borders. Anyone adept at extrapolation surely would be confounded by the present entrepreneurial torpor.

This state of affairs affects the match between Jean's aspirations and the realities of his engineering career. The youth of today is both idealistic and sophisticated and finds it difficult to understand why such an affluent province fails to use its engineering resources in a more imaginative way. Jean has a real sensitivity towards the social implications of engineering and expects his education to relate technology to life style, professionalism to humanism. He wonders why Canadians responded so magnificently to the emergencies of war, but so sluggishly to the challenges of peace; he is determined to improve the situation.

Jean finds the prospect of engineering exciting and challenging, but bewildering in the enormous variety of careers available to the engineering graduate. For one thing, there is an increasing body of opinion that engineering represents a splendid background for a liberal education, since an understanding of technology is an understanding of one of the most important social forces of this generation. Thus, many students who do not intend to practise engineering elect it as a fundamental education for careers in teaching, medicine, law and business.

For those who intend to practise the profession, two types of careers are admirably served by an engineering education:

(1) The first is, of course, a full career in "hard engineering", which concentrates on the translation of the principles of science into the satisfaction of the needs of man by devices, structures, vehicles or processes.

(2) There is a rapid increase in the number of engineers who take positions in management at all levels. Indeed, statistics demonstrate quite clearly that the majority of engineers follow this path out of their early technological employment.

Of course, the vagaries of opportunity, of social influences, and of general temperamental development will shape Jean's decisions and the pattern of his career. Nevertheless, it may be worthwhile to summarize the activities in which engineers do engage, so that he may cross-check this list with the most probable source of employment in each (Table 1-1).

Such a list may be incomplete, but it underscores the varied opportunities provided by an engineering education — a fact chronically under-emphasized in guidance advice, which too often appears to be woefully ineffectual and outdated. As Jean proceeds in his course, he will begin to identify his talents, and to match them up with opportunities for exploiting them.

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What is the state of engineering in Ontario as we move into the 1970s? There is a hesitation in the growth of engineering enterprise, resulting from the present North American economic slump, together with the accompanying wide-spread inflation and high cost of risk capital. Many Ontario executives, already chronically

Table 1-1

ENGINEERING ACTIVITY

Type of Engineering Activity	Industry	Government	University	Self-employed (including consultants)
1. Design	X	X	X	X
2. Systems Analysis and Synthesis	X	X	X	X
3. Physical analysis	X	X	X	X
4. Project Management: (A) Technical control (B) Cost Control (C) Time Control	X	X		X
5. Business Management (technical endeavour)	X	X		X
6. Industrial Management: (A) Productivity (B) Marketing (C) Labour (D) Resources men, money, materials)	X		X	X
7. Information Management: (A) Data storage, retrieval (B) Pattern recognition	X	X	X	X
8. Maintenance engineering	X	X		
9. Reliability engineering	X	X	X	X
10. Value engineering	X	X		X
11. Test Engineering	X	X		
12. Quality control (quality assurance)	X	X		
13. Operations research	X	X	X	X
14. Production engineering	X			
15. Specification engineering (components, materials, systems)	X	X		X
16. Research engineering	X	X	X	X
17. Research management	X	X	X	X
18. Project or process engineering	X	X		X
19. Teaching	X		X	
20. Administration (expediting, contracts)	X	X		X
21. Technical sales	X			
22. Technical Marketing	X	X		
	22	18	10	15

conservative, have retreated to custodial roles, beset as they are by sharply rising labour costs; as a result, innovation is in the doldrums at a time when it is most urgently needed. And yet, in the spring of 1970, there was a brisk market for engineering graduates at salary levels slightly better than in 1969.

Ontario is in the midst of a move towards industrial sophistication, and so it is reasonable to expect that the market for engineering graduates certainly will be sustained and probably will improve during the years of the present decade. Not only is the outlook attractive quantitatively, but there has been a sharp improvement in the quality of professional careers which will, if anything, intensify when innovative activity again picks up its pace.

The rate of development for science-based industry poses one of the most difficult questions relating to this study. Most engineering deans were far too optimistic in their views as to the speed at which sophisticated engineering activity would emerge in the sixties, and this optimism has been reflected in the nature of the engineering programs in our universities. The accuracy of these predictions for the next ten years will have a strong bearing on the success of this report, the main purpose of which is to recommend an educational route by which our young people can develop into citizens who will be at ease with their environment, and equipped to contribute to the quality of life during the balance of this century.

With the population density now reaching a point where people are posing a significant threat to the environment, it is clear that over the next decade, an increasing number of engineers must find careers in the broad area of ecological stabilization and reclamation. Increasingly, they will be drawn into problems working with biologists, sociologists, economists and politicians. They will be confronted with socio-economic decisions as to the balance between economic gain and social depreciation, between capital expenditure and the enhancement of life of the individual. Many engineers will have to learn to function as members of interdisciplinary teams, and will require a broader education in the life sciences and the social sciences in order that their technological decisions will have the desired social impact.

As technology has become a major and frequently irreversible social force, the need has developed for a new kind of liberal education — one grounded in technology, rather than one based on the arts as in the more leisurely and contemplative days of Cardinal Newman. Sir Eric Ashby has said:

> In order to adapt itself to an age of technological specialization, the university must use specialist studies as the vehicle for a liberal education. Indeed, what is needed is nothing less than a revision of the idea of a liberal education. The *Oxford Dictionary* defines liberal education as education fit for a gentleman. That is still an acceptable definition; it is the idea of the gentleman which has changed. A century ago, when Britain awoke to the need for technological education, a gentleman belonged to what was called the leisured class. The occupations of his leisure did not require any knowledge of science or technology. Modern gentlemen do not belong to the leisured class. Many of them work something like a seventy-hour week, and more and more of them are finding that their business requires expert knowledge. Even members of the House of Lords are called upon to make decisions about radio-active fall-out, overheating during supersonic flight and the strontium content of human bones. Senior civil servants have to deal with highly technical policy. . . . Even such a gentlemanly subject as the state of the River Thames cannot be understood without some knowledge of oxidation and reduction, detergents and the biochemistry of sewage.[1]

This statement, written in 1959, was prophetic of the current situation in Ontario.

Unfortunately, faculties of humanities and social science have failed to include within a liberal education our most profound sociological force. To a question asked on every campus in this province, we uncovered only a single instance where a Dean of Arts had requested a course from the faculty of engineering! It seems clear that in this decade a new type of liberal education must develop, with engineering as its core, as suggested by Ashby; it will have its genesis in our engineering schools. Equally important, this will provide a favourable environment in which to develop courses in technology, designed specifically for students in the humanities and social sciences.

The history of technology is a brief one, and has evolved in three distinct phases. As man became less of a nomad and more part of a community, his earliest demand was for materials — for clothing and housing to protect him from the elements, for tools to till the earth and to kill his quarry. Much later he developed skill in the conversion of energy — to provide light, to heat his living space, and to power his engines. Then very recently, in a mere two decades he has become much more sophisticated about the management of a third commodity: information.

The management of information has been a triumph of engineering accomplishment since 1950 — in the discrimination, collation, and calculation by computers, in the transmission of messages with great speed and over great distances, and in the retrieval of relevant information from a burgeoning stockpile. Over the present decade we should see engineering schools specializing in the discipline of information systems engineering, newest and possibly the greatest accomplishment of technology, for it includes such elements as computer technology, communications, systems analysis and network synthesis.

The foregoing paragraphs have been written in an attempt to try to underline the trends that must be taken into account if Jean is to receive a reasonable basis of education for a life that will extend into the second millennium. We say "basis" because the winds of change are whistling round his ears, and his education must be a lifelong process, with frequent mid-course corrections, as technology and social mores evolve.

This study was initiated in response to a recognition that the development of engineering education must follow some charted course and not merely meander. Today, the atmosphere of technological and social change is so vigorous that powers of prospection have limited horizons and retrospection becomes steadily less useful. Therefore, the current study should be the forerunner of a continuing corrective mechanism, to be updated at frequent intervals — perhaps every five years. This brings into sharp focus the necessity of implementing changes as quickly as possible. Inertia and lag are characteristic of educational change, and the need now is for incisiveness, as the second derivative of change — the rate at which change occurs — is steadily increasing.

[1]Eric Ashby, *Technology and the Academics* (New York: Macmillan Co. Ltd., 1959), p. 81.

The elements of a plan for engineering education are numerous and complex. They comprise what a systems engineer calls a highly interactive system, and must include the mutual influences of at least eight groups:

(1) Students,
(2) Teachers,
(3) University,
(4) Engineering profession,
(5) Employees,
(6) Community,
(7) Economy,
(8) Society at large.

This list represents twenty-eight interfaces which make up the substance of this report. At this point, it would be futile to ask all the questions that had to be answered — they are better treated in the chapters that follow. In an attempt to provide answers, the study group employed a broad spectrum of resources, and met with hundreds of students, educators, employers and practising engineers. The number of data assembled is prodigious, and probably it is worth repeating that this report is principally about the student, in spite of a mountain of statistics tending to blur that fact: the quality of Jean's education experience must be our primary concern. From the conversations we have had with engineering students, we are convinced that any contribution that can be made to improve their educational experience will be abundantly repaid, because their development as professionals will have such an impact on the society about them.

2

THE THRESHOLD

The atmosphere of rapid change in the educational patterns of Ontario has a particularly strong influence upon its engineering faculties, because engineering education depends so heavily on prerequisite knowledge. One of the difficulties that faced the study group was the development of admission criteria compatible with the credit system now evolving in the high schools. Other professions do not have this problem to the same degree. Medicine and law are studied as post-baccalaureate programs, while dentistry and theology deal to a large extent with subjects encountered for the first time at the university level. Even undergraduate courses in humanities and social sciences should be less affected by the new curricular developments. This leaves science and engineering as the two most vulnerable divisions of university work. When one considers the extent of this vulnerability, and the direct influence of engineering graduates on the environment and on the economy, one cannot help but be dismayed by the negligible amount of communication that existed between the Ontario Department of Education and the Committee of Ontario Deans of Engineering. It is this lack of communication that is the source of our dilemma.

The secondary schools of Ontario have begun to phase in a new educational pattern with more local responsibility for curricular content, and a system of credit assignment that will permit a broader choice of paths to the secondary school Honour Graduation Diploma. It is predicted that over the present decade the percentage of high school graduates entering university will rise from about 21% in 1970 to over 30% in 1980. At the same time, the proportion of high school students electing physics and chemistry has been dropping (Figure 9-3), while registration in the life sciences has been increasing. In all likelihood this trend will continue for a number of years before levelling off.

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Since 85% of the undergraduate engineering students come from the Ontario secondary school system, there will be only a very gradual increase in the number of potential engineering students if engineering schools continue to require physics and chemistry at the senior level as criteria of admission. The results of a study on the probable demand for engineers up to 1980 are presented in Chapter 9 (page 55). It is clear from these figures that if the supply of engineers is to meet the demand over the next ten years, changes will have to be made in the requirements for admission.

The new, less-structured secondary school curriculum should produce graduates who are more broadly educated, and who have achieved a clearer grasp of the kind of value judgments they will be called upon to make in the future. But the very nature of such improvements — the wider spectrum of choice presented — puts a special emphasis upon the skill and judgment of guidance counsellors; there is little evidence to suggest that they are equal to the task. Indeed, there appears to be a general feeling among secondary school graduates that guidance programs have been ineffectual even in the simpler days of rigid academic programs. Therefore, there is room for considerable concern over the possibility that students may be improperly directed in secondary school, and so reach graduation with an assembly of credits inappropriate to current engineering admission standards.

The faculties of engineering will face three choices:

(1) Retain the present requirements of physics, chemistry and mathematics. This would result in a rate of rise in the number of graduating engineers which is less than the rise in demand. As the shortage of engineers becomes more severe, probably some correction will occur to restore the balance, but there could be a considerable lag before it takes place.

(2) Adopt admission requirements in the direction of fewer specified subjects, while maintaining an appropriate standard of performance. This would make it possible for more students to enrol in engineering, but most certainly will result in higher failure rates in the freshman year. Again, a correction should occur with developing experience.

(3) Make vigorous representations to the Minister of. Education, with a view to illustrating the impact of the new system on engineering education.

The study group has come to the conclusion that the best course to follow is to develop relatively unstructured admission criteria. Mathematics at a senior level must continue to be specified, since it is the unifying discipline of all engineering. Therefore, we recommend that:

(2:1) beyond senior mathematics the secondary school Honour Graduation Diploma should be a sufficient requirement, set at a level of performance decided upon by the faculties of engineering, who must become increasingly dependent on their own evaluation of secondary schools in their districts, and upon the anecdotal reports of the principals.

Such a recommendation raises the spectre of the university being forced to provide elementary chemistry and physics, when already there is too little time available in the curriculum. This is not the intent, and it should soon become clear to engineering aspirants that without physics and chemistry their chances of success are in jeopardy. But it will permit entry to able students who have received improper guidance, or who have changed their career plans. It is encouraging that high school principals and guidance counsellors have expressed to the study group an interest in receiving feedback on the performance of their graduates.

3

THE UNDERGRADUATE ENVIRONMENT

"They push 1st year buggers like a herd of mooses."

—Response from a Waterloo student.

In Ontario there are eleven provincially-assisted faculties of engineering, and one, the Royal Military College of Canada, that is fully supported by the federal government. This latter institution has been included in some aspects of our study and a recommendation will be made with respect to it. However, the main focus of attention will be on the other eleven, which fall into three categories of size, based upon enrolment figures for 1969-70:

University	Undergraduate Enrolment	Graduate Enrolment	Total Enrolment
Waterloo[a]	2,349	456	2,805
Toronto	2,199	625	2,824
Queen's	1,360	168	1,528
Carleton	538	115	653
McMaster	504	184	688
Western	442	79	521
Windsor	401	87	488
Ottawa	369	156	525
Guelph[b]	157	23	180
Lakehead[c]	158	—	158
Laurentian[d]	51	—	51
TOTAL	8,528	1,893	10,421

(a) Operates on cooperative scheme.
(b) Offers program in agricultural engineering only.
(c) Offers first and second year only in degree program; engineering technology students also included.
(d) Offers first and second year only in degree program.

In the fall of 1969, a draft questionnaire was drawn up to be answered by the Ontario engineering schools. This was subjected to a review by each dean of engineering in order to assess its appropriateness, and a revised version was sent to each faculty of engineering, for response by April 15, 1970. From then until July 1, hearings were conducted by the study group with every engineering faculty in the province.

To obtain information about engineering educational philosophy in Europe, the director visited institutions in Germany, France, Sweden and Great Britain. Other Canadian campuses visited were the University of British Columbia, University of Alberta, University of Saskatchewan, University of Manitoba, Brock, Trent and York Universities, Ecole Polytechnique, University of New Brunswick, Nova Scotia Technical College, and Memorial University of Newfoundland. In the United States we visited the University of California at Los Angeles, Berkeley and Irvine, Stanford University, Harvey Mudd College, Dartmouth College, the State University of New York (Buffalo), and M.I.T. Although the effect of so many visits and shades of opinion is somewhat kaleidoscopic, the study group believes the opinions which it has been able to develop were formed against an unusually broad background of information.

On the basis of this study, it can be stated with confidence that the engineering undergrad-

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uate in Ontario is being afforded the opportunity to graduate as a good engineer. While there are variations in the cost of different programs, and in the emphasis on graduate studies and on the degree of industrial and professional involvement, at the same time, there is an encouraging sense of purpose and enthusiasm on the part of both faculty and students. Indeed, a matter of concern to the study group is the impression that the differences among these schools are not significant. A wider spectrum of educational philosophy and technique is evident within a radius of seventy-five miles in the State of California than throughout the entire province of Ontario. Such a sameness cannot be blamed on the present system of financing, because these faculties came into being prior to the birth of the Basic Income Unit. Nevertheless, the interpretation of the system of formula financing adopted by several universities has militated against innovative breakthroughs in teaching or the development of new lines of endeavour.

Formula financing in Ontario has as its aim the determination of income for each campus, not the establishment of guidelines for expenditure within the university. Some universities have adhered strictly to these terms of reference, but others have allowed the head-count to determine the operating budgets of faculties or even for the smaller subdivisions. This type of "decision by head-count" can represent an evasion of responsibility by those who should make strong decisions about educational philosophy and policy, and can become a stultifying influence in planning and development. It is ironic that the features that make some schools stand out from the group almost invariably are financed otherwise than by the Department of University Affairs—usually by a division of the Government of Canada or a granting agency in the United States.

This report opened with the statement that it was about students, and at this point it is appropriate to turn back to our primary concern. In the course of our interviews, we talked to several hundred potential engineers, and came to appreciate that they had this common characteristic: an eagerness to improve the system. The most persistently voiced complaint has been a disappointment with the first two years of their university experience; they find the course unimaginative and lacking in opportunity for personal innovation. This feeling is most intense in those schools which have a common first year with science. The study group recommends that:

(3:1) innovative opportunity in the form of design should be brought into first-year engineering programs, despite the elementary character of the design examples. The gain in motivation and morale would amply repay the expenditure of time.

We talked a good deal about the general education afforded by engineering studies. The upsurge in students' concern for the quality of life, and the intensity of their social commitment appears to be more than a passing phase, and attention must be paid to the demand for more meaningful education in the humanities and social sciences. General dissatisfaction was expressed over the content and presentation of such work, whether it was a part of the regular course offerings in the university or, as is seldom the case, specifically designed for engineers. It will take bold new steps to solve this problem, for many compromise solutions have been tried and most have been found wanting. An editorial in *The Engineer* had this to say:

> The problem of broadening engineering education, always buffeted between high ideals and too little time, is assuming a new sense of urgency. . . . There seems to be a beginning of communication between engineering and social sciences, but there is still a complete disassociation between engineering and the humanities. Interaction between engineers and social scientists will introduce real-life complexities to engineering education; communication with humanists will widen overall responsibilities.[1]

It would appear that the limitation of time can be overcome since many students expressed a willingness to devote a further year to a meaningful program in the social sciences. Moreover, it seems inevitable that "liberal engineering" must have its genesis in an engineering school with a program whose aims are akin to those expressed by Gerald Walters:

> . . . Science and art share a common obligation to keep our minds open and to keep them deep, to keep our sense of beauty and our ability to make it, and our occasional ability to see it in plans remote, strange and unfamiliar. Not an easy task in a great open, windy world — a rugged time of it no doubt, but now as complementing and no longer antagonistic modes of experience.[2]

Dr. Allen B. Rosenstein of the School of Engineering at U.C.L.A. has completed a comprehensive study of engineering education[3] and

[1] *The Engineer*, March-April 1970.

[2] Gerald Walters, "Unity of Knowledge and Experience", *Technology and Society*, Vol. IV, No. 2 (1967) 44-6.

[3] A. B. Rosenstein, *A Study of a Profession and Professional Education.* (Los Angeles: University of California, 1969).

one of his conclusions is particularly relevant to the Ontario scene. He found substantial redundancies in engineering curricula (e.g. he cites one school where Hooke's Law was treated in some detail six times). Dr. Rosenstein asserts that, even allowing for deliberate repetition, a respectable engineering curriculum of only three academic years in length could be designed if it is regarded as a project in systems analysis. On the basis of this model, an exciting program has been developed at Harvey Mudd College (Claremont College System, California) which is precisely "liberal engineering". It is a four-year program, fully accredited by the Engineering Council for Professional Development. The study group is convinced that such a program should be introduced into the Ontario engineering education system and recommends that one school make this its major focus of effort.

When one considers the great engineering schools of Europe and the United States, one is struck by the number of outstanding polytechnic institutes. This prompts the idea of a self-administered Ontario Institute of Technology with its own Board of Governors and Senate. It could be either on an existing campus, or established quite separate and apart from any university. There is ample evidence that some faculties of engineering believe the present campus environment to be stultifying, particularly where the engineers are recent arrivals. When students were asked whether or not they favoured such a separate institute, the answer was almost universally an emphatic "No!" The reason given for this response was the substantial educational experience gained on a multi-disciplinary campus in associating with other students. Many insisted that coffee shop discussions were as important as any of the formal course programs in developing a broad social consciousness. When a similar question was asked of senior non-engineering academic personnel, the response was much less clear-cut. The reply ranged all the way from the emphatic statement, "It would be a real tragedy", to a pallid, "I suppose we would miss the engineers". This general lack of concern is by no means restricted to Ontario, for as Sir Eric Ashby points out,

> Higher technology is admirably taught, and it is the object of much distinguished research. But it has not been assimilated into the ethos of the university. Universities have adapted themselves considerably to the scientific revolution, but in adaptation to technology — one of the consequences of that revolution—they have not yet reached equilibrium.[4]

Only at Toronto does the engineering faculty appear to be fully assimilated into the university, as an equal member in a vigorous intellectual partnership. Such assimilation takes time — there the faculty of applied science has coexisted with the other faculties for more than a century.

The study group was impressed with the value placed by the students on the educational experience available in a multi-faculty university community. At the same time, it would be worthwhile to try the experiment of a self-administered Institute of Technology. Not only does it offer promise of more unfettered educational experimentation but also, as was pointed out in the submission of the University of Toronto, "A major substitution focus on a single strong technological university would provide a more stimulating challenge to the system than the evolutionary development of the status quo." Therefore, we shall recommend (page 74) that one faculty of engineering be reorganized as an independent technical university, with its own Board of Governors and Senate.

The motives for studying engineering appear to range all the way from a desire for a general education to an ambition to become a member of a university faculty. There is no evidence of widespread interest in joining the world of industry, and this reflects the apparent unadventurous posture of so much of Canadian industry — a picture that shows little sign of improving. Indeed, industrial experience during the undergraduate period often tends to quench rather than kindle enthusiasm. In a final-year group at the University of Waterloo only 32% of the class signified an intention to pursue careers in industry.

Very few declared they had an interest in self-employment, either as entrepreneurs or as consultants. In general, the student sees his future in the role of an employee-engineer. Such unadventurous student aspirations are disturbing, and bring into question the appropriateness of the present educational spectrum either to excite the imagination of the unawakened, or to provide a proper curricular structure for the large number who will be pursuing predominantly non-technological careers.

It is unrealistic to believe that the many and diverse motivations of students can be satisfied with the one curricular assembly which has been attempted in most Ontario engineering schools. For this reason, the study group recommends the development of diversity by the acceptance of more definite roles in undergraduate education. In addition to the "liberal education" role already discussed, we feel that two schools should

[4]Ashby, *Technology and the Academics*, p. 88.

specialize in the broad field of information systems engineering, another in ecological engineering, and a fourth in agricultural engineering. These same foci of specialization should extend into graduate education so that on each campus there may develop, over the next ten years, distinct concentrations of excellence. Specific recommendations in this regard are given on pages 71–83

The students' response to a separate questionnaire provides further food for thought. They regard as of equal importance in their educational experience the ability to identify and formulate problems in quantitative terms, and the development both of a "sense of innovation" and of a "feel for the socio-technological relationship". Some students believe that our engineering schools should encourage student exchange programs with Quebec, as a factor in the maintenance of Canadian unity. A student letter on this subject is reproduced in Appendix A.

Their recommendations for ways to improve the curriculum include:

(1) earlier design experience;

(2) more freedom of choice of elective courses;

(3) more sense of an integrated educational plan;

(4) More "hard engineering" material — that is, more applied science, as opposed to theoretical concepts.

In general, satisfaction was reported with individual courses, but the majority felt they were allowed too few glimpses of the overall plan behind their particular curricular programs. The general criticism was stated succinctly by one student who said, "It is attitude rather than content, style rather than subject matter, and the system rather than the course, which are the causes of student despair." Despairing or not, 60% of the students responded that, armed with their present experience, they would enrol in engineering again, while 20% said they would choose another discipline.

The number of women enrolling in engineering is increasing slowly but still represents a very small minority. This is regrettable, because the nature of modern engineering is such that most engineering occupations could provide women with promising careers. While female enrolment is encouraged, it would appear that in many instances in the high schools girls have been counselled against considering engineering as a professional career. An interesting paper on this point by an undergraduate student is included in Appendix A.

The study group spent a good deal of time meeting with members of Ontario engineering faculties and this has resulted in a number of opinions. One has been noted: a reasonable education experience is available in all of the schools, although often it is not well matched to the aspirations of many students.

In the present context of Ontario secondary school preparation, and the short university academic year, it seems clear that at least four years are required for the undergraduate course. No real pressure has been developing to extend it by a fifth year. Rosenstein's observation about curricular redundancies should be taken seriously, to ensure that student and faculty time is being wisely invested, before any alteration in the length of the programs is contemplated. The study group has become convinced that the current practice of beginning technological education directly out of secondary school is a good one. The student desire for an early contact with engineering is intense, and constitutes a strong argument against a preliminary general program.

Current curricula reflect the conviction of the deans of engineering that Canada's industrial sophistication would develop more quickly than it has. The engineering program has a high content of mathematics and science with a rather low proportion of time being devoted to technology and business administration — apparently on the premise that a significant fraction of engineering graduates would be making their careers in the innovative activities of research, development and design. The lack of any reliable predictors for technology, coupled with the current air of uncertainty in the economy and of policies relating to national resources, makes it difficult to match curricula to the future demand for skilled personnel. Educational lags cannot help but be substantial. Usually it takes at least two years to implement a new university course, up to four years before the student who completes that course enters professional life, and another year or two before his efforts are felt in the profession. Thus trends must be identified at least seven years before any significant feedback can be realized from the educational system. Since it seems inevitable that the Canadian economy must develop through the application of "high technology", no strong argument can be advanced for reverting to the hardware-oriented curricula of the past. In any case, such needs are being met by the Colleges of Applied Arts and Technology.

We do not wish to imply that laboratories are becoming of less importance. Indeed, the laboratory is still the place where the student meets the physical world, and becomes acquainted with the instruments and techniques of his profession. Laboratories should be used by the student to gain information, judgment and design experience, rather than the traditional use by instructors to demonstrate known laws of science. A laboratory should be exciting to the student, a place to kindle the flame of invention and ingenuity. It is there that the student learns the rudiments of modelling, simulation and testing.

We recommend that:

(3:2) each engineering school undertake a study of its teaching laboratories, and establish ways in which the student will use them to obtain design experience.

It is surprising that universities have not developed depreciation policies in respect to laboratory equipment. This is the pattern for industry, which begins to write off equipment on the day of installation, in order to build up reserves for replacement, as well as for tax purposes. If a similar procedure is not adopted for university laboratories, they will soon become museums. Furthermore, as the equipment ages, present practice will have the undesirable side-effect of shifting curricula away from the laboratory towards more class-intensive and software-oriented programs. Such a shift could reduce the versatility of the graduate. Therefore, we recommend that:

(3:3) universities establish a depreciation policy with respect to engineering laboratory equipment, so that before it becomes obsolete or worn out, adequate reserves are generated for replacement.

A good argument can be made in favour of more engineering/business management interaction at the undergraduate level. More than half the students enrolled in M.B.A. programs are engineers, and ten years after leaving university, more than half of Ontario engineering graduates are in management career patterns. Furthermore, increasing numbers of very senior positions, both in industry and government, will be filled by engineering graduates. Such trends have not been given sufficient weight in planning undergraduate curricula, and should be reappraised with confidence as to their relevance to the future. Indeed, the development and maintenance of an integrated curricular plan is of such importance that the study group makes this recommendation:

(3:4) Each faculty should have a standing committee on curriculum, with substantial student representation, whose responsibility it is to ensure that there is an articulated sequence of courses in each stream. Such a committee should regard as its prime function the continuous monitoring and updating of the curricular system.

There have been recurrent suggestions that the traditional departmental divisions of engineering education are outmoded, and some Ontario faculties (e.g., Carleton) have replaced them with names and structure conforming to divisions of study instead of professional classifications. The study group could find neither strong objection to such a development, nor any compelling reason to recommend it. Since it is in the nature of an evolutionary change, beginning in the graduate school, such a decision will be reached at a different time in each faculty, as a function of the character of its research and graduate activity.

In view of the sluggish development of university/industry interaction, it is suggested that the following experiment be made by some faculty of engineering located near a large industry. A satellite campus would be established on the plant site, staffed by university faculty who are half-time industrial employees. The student body would consist of third-year students who are also half-time employees; they would complete their third year in one complete calendar year, in this industrial-academic environment. Such an experiment should serve to develop more vigorous liaison between campus and company, and would provide considerable experience for faculty and students, as members of an industrial task force. This suggestion is an extrapolation of the cooperative plan for engineering education followed by Waterloo. It is on a much smaller scale but with professorial involvement, and is highly dependent on the nature of the industry in the community. It should not interfere with the Waterloo program, which works well and provides valuable experience to the student.

In this chapter an attempt has been made to take account of some of the considerations behind undergraduate curricular development. It is artificial to think of undergraduate education separate and apart from graduate studies — they are, in a very real sense, an educational continuum, particularly as interdisciplinary involvement develops. Nonetheless, there are differences, not the least of which is the extent of the demand for the services of holders of a graduate degree as against that for those with a bachelor's degree. Because of these differences, the graduate educational environment will be discussed separately in the next chapter.

4

GRADUATE STUDIES

In the first chapter of this report, we considered the motivations and aspirations of a typical student, Jean, as he left secondary school to begin his first year of professional education. For purposes of continuity, we must assume that Jean is in that 25% of engineering graduates capable of successful completion of a program of graduate studies. Despite such qualifications and the opportunities available for advanced work, there is more than an even chance that Jean will elect to enter the practice of his profession as soon as he finishes his baccalaureate studies. Engineering differs from most other disciplines in that about 70% of its students acquire industrial or consulting experience before returning for graduate work. Typically, Jean will work at his profession for two or three years, during which time he will develop a strong desire to extend his knowledge, and possibly to develop his expertise in the direction of a career in research or development. He will seek out the professor whose special research activity corresponds most closely to his own interests, and then apply to enrol in the appropriate graduate school. Thus, he will become a member of a group which, because of those industrial years, has a somewhat higher average age than that of postgraduate students in other disciplines. Let us examine the characteristics of Jean's new environment.

A hallmark of the sophistication of an intellectual discipline is the breadth of its generalities. The laws of physics, for example, are very pervasive, while those of psychology are quite circumscribed; physics is at a much more sophisticated stage than are the social sciences. As these generalities evolve, their broad applicability causes the boundaries between disciplines to become increasingly fuzzy, and sometimes to disappear. In a university, the erosion of disciplinary identification is seen first in the research laboratory or design office, whence it spreads into the lecture room, and ultimately to the undergraduate program.

Our engineering schools have a particularly important role to play in the development of interdisciplinary research programs, not only because engineering is a "bridge discipline", but also because engineers have made it their business to understand the characteristics of complex interacting systems. This makes the research engineer uniquely valuable in interaction with the life scientists (bio-medical electronics, health care delivery systems, physiological intrumentation), the social sciences (socio-technological forecasting, mathematical modelling) and the physical scientists (scale-up of processes, hardware development, simulation and optimization). Thus the 1970s should see a vigorous thrust in interdisciplinary research and education — an opportunity that must be exploited to the limit.

There is a good base on which to build this interdisciplinary activity, thanks to the dramatic development, over the past decade, of engineering graduate work in Ontario. An indicator of this fact is the rise in enrolment of graduate students, from 295 in 1960 to 1,900 in 1966,[1] with a proportionate increase in the number of research directors. The accompanying aggressive recruitment of faculty brought into the universities a large number of younger members educated in science-intensive programs. Such individuals represent a resource of engineering talent predisposed to research projects of considerable interdisciplinary scope, and at a time when there has developed a very real awareness of the interdependence of disciplines.

Graduate studies in seven of the provincially-supported faculties of engineering have been developed between 1960 and 1970. This decade has been one of great advances in technology, particularly in the area of data assembly, information management and computation and control by computer. There has been a strong incentive to develop graduate studies, with the result that by 1969 there were 1,279 candidates for the master's degree and 614 (544 with the master's degree) for the Ph.D. degree enrolled in Ontario engineering schools. Such rapid growth has raised the question of the ability of so many faculties to finance and sustain first-class graduate programs over the full spectrum of disciplines. Because of this concern, in 1967 the Ontario Council on Graduate Studies (OCGS) instituted an appraisal scheme for suggested new programs; within its terms of reference the scheme works well. The decisions of OCGS have been based on the qualifications of faculty and on the adequacy of library and laboratory facilities to ensure reasonably uniform standards of excellence. Graduate activity across the province has gained considerable balance, with centres of excellence in particular areas now beginning to appear. However, it is evident that employment prospects are likely to be quite bleak for the hundred engineers who will graduate with the Ph.D. degree in 1970; looking back, the question arises as to whether career prospects should have been included in the list of criteria for program initiation.

The strategy should be to build on strength, so that significant concentrations of effort can emerge over the next ten years. Examples of such developments are the Institute for Aerospace Studies at the University of Toronto, the Canadian Institute for Guided Ground Transport at Queen's, the Institute for Materials Research at McMaster, and the Management Science Program at Waterloo. Now that examples of special excellence are appearing, opportunity for their development must be engendered by deliberate avoidance of duplication of effort. The concept of "centre of excellence" should be in the sense of focus of interest, rather than of geographic location.

Consideration has been given to the problem of a balance between supply and demand; a study of the need for engineers with the bachelor's degree has been completed and is reported elsewhere (Chapter 9). It shows that a normal build-up of enrolments in the undergraduate programs should parallel demand until 1980. There are many indications that the master's degree will assume increasing significance in the 1970s. This is the level of engineering education recommended as a first professional degree in the Goals report of the American Society of Engineering Education. Dean Maslach of Berkeley maintains, "The rallying point for engineering education in the next decade will be the master's degree." The trend is to larger numbers of graduates entering "course-intensive" master's degree programs, and this is quite appropriate to the nature of the demand for engineering services. There seems to be no justification for curtailing enrolment for work leading to the master's degree.

Within the Canadian environment at the present time, it is difficult to rationalize doctoral programs in engineering. Most of these programs were set up in the conviction that science-based

[1]See Appendix B, Table B-3.

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industry would experience vigorous development during the 1960s. However, this strong thrust failed to materialize, and now there is retrenchment in some of the subsidiary industries, with a reduction in the Canadian component of their research and development effort. Today, in the light of the apparently modest employment prospects in industry, the opinion is being voiced that programs leading to the Ph.D. are too extensive. For example, the Science Council of Canada has pointed out that "the supply of Ph.D.'s is now big enough to fill the currently low demand for Ph.D.'s in research and development . . . this is Canada's first chance to really start putting Ph.D.'s into key positions throughout the economy and not just in the R and D laboratory . . . the universities in Canada *annually* produce more Ph.D.'s in science and engineering than the *total* stock of Ph.D.'s in Canadian industry."[2]

The universities have been Canada's most aggressive recruiters of Ph.D.'s over the past decade of vigorous growth in our engineering schools. Now this growth rate will diminish, providing an opportunity both for consolidation of effort and for the development of excellence. Based on past statistics, the attrition rate of academic staff in Ontario engineering schools will be about 3.4% per year. Thus, over the present decade approximately 625 academic engineering positions should open up in Ontario, most of which will demand a Ph.D. degree. (See page 54). While it is to be hoped that all such positions will not be filled by newly-graduated candidates, this figure is quoted to show that university employment should continue to constitute a significant market for engineers with doctorates. If current enrolment trends continue, it is anticipated that 1,400 Ph.D.'s in engineering would be awarded in Ontario over the same period of time; so that the expected number of academic vacancies would amount to about 45% of the total number of Ph.D. degrees to be conferred.

The federal government, in its concern over the slow development of Canada's secondary industry, has set up a series of incentive programs (IRDIA, PAIT, IRAP, etc.), to stimulate expansion through innovation. In addition, fellowship programs have been initiated to encourage engineers to upgrade their qualifications (PIER Fellowships), and to persuade industry to employ engineers who hold doctorates (Industrial Post-doctorate Fellowships). These programs are exploratory in nature, and it is too early to evaluate their impact. The Ph.D. engineer requires time to realize that the techniques and strategies which he employed in his graduate work have applicability far beyond the research and development laboratory. Also, the industrial employer must come to realize that the Ph.D. can be an asset in a wide variety of assignments, including operations research, market research and production engineering. At the moment, there is an over-supply of doctoral graduates in engineering, and indeed the Ph.D. degree may close the door to many an engineer seeking employment, because industry assumes that his field of interest is too narrow.

An estimate of the point in time when supply and demand will coincide can only be made on the basis of a comprehensive manpower study. It involves consideration of the career patterns of engineering graduates at all levels as well as the recruitment patterns of all potential employers. Accordingly, the study of engineering manpower is dealt with in detail in Chapter 9. It forms the basis for our belief that the current trend of enrolment in doctoral programs will result in more graduates than can be absorbed into the economy. This forces us to deal with the frequently-debated question, "Has a university any responsibility for the future careers of its graduates?" A satisfactory resolution of this question is difficult, and it must be considered in company with a second question, "At a time when educational costs are becoming prohibitive, should we continue programs which cannot be justified economically?" The two questions taken together are more easily answered than either alone. Therefore, the study group will make the recommendation that immediate steps be taken to reduce the enrolment of Ph.D. candidates in Ontario to a total of 450, with a view of graduating no more than 125 Ph.D. engineers each year. Although this number represents a drastic curtailment, it is consistent with employment forecasts, which should be reviewed periodically.

While enrolment in programs leading to a master's degree should be allowed to increase naturally, it will be recommended that they not exceed 1,850 by 1980. In this study it became apparent that such graduates are being employed because of their extra knowledge and maturity rather than for the research experience gained in graduate school. This justifies considerable experimentation with the character of the educational experience offered as qualification for the master's degree, particularly as service industries expand and proliferate. (See Chapter 9.)

A levelling-off in total graduate enrolment in the schools of engineering should not be a cause

[2]*Pensées*, 5 (August 1970), p. 18.

of concern, since it will present a much-needed opportunity for consolidation after the vigorous expansion of the past few years. There has been a general and yet incorrect assumption that engineering research must involve graduate students. This has led to the situation where most engineering faculty members, even the relatively inexperienced younger ones, function as research managers rather than as active participants. A decrease in the number of doctoral candidates could have several desirable effects:

(1) There will be an opportunity to redress the present imbalance between undergraduate and graduate effort. Existing undergraduate programs would benefit from more experimentation and more intense effort to engage the imagination of the undergraduate engineer at the very beginning of his university experience.

(2) More faculty will be able to undertake projects in the neglected areas of engineering synthesis, such as device and process design, systems engineering and production engineering.

(3) There can be more direct involvement of faculty with Canadian industry, either as independent consultants or through on-campus research institutes. Many engineering faculty, now performing perfunctory research, can make a greater contribution in shorter-term technological projects.

(4) There would be a general upgrading in the quality of research in the graduate schools, and stronger research teams grouped around the most skilful directors. On this point Dr. O. M. Solandt, Chairman of the Science Council of Canada, has made this comment:

> I do think there should be fewer and better people doing research. A good university teacher does not need to do research himself, but he certainly must live and work in an environment where there is close contact with research. I am quite certain that in Canada we are spreading our resources too thinly. The effective value of a research grant has risen very little in the last ten years and is a small fraction of a similar grant in the United States. If we cannot get more money for basic research, I am sure that our present expenditure in Canada would make a greater contribution to world science if it were spent by fewer people.[3]

One of the consequences of a smaller number of doctoral candidates will be an annual reduction in total costs of more than two million dollars. It is important that some of this saving be redirected into undergraduate programs in order that the other recommendations of this report may be effectively implemented. The assumption of special roles by engineering schools will need financial support to offset possible temporary shifts in enrolment patterns. Such financial adjustments will have to be made if the desired improvements in the system of engineering education are to become a reality.

It is regrettable that part-time graduate studies have met with such indifferent success. The record of attempts is distressingly similar: too many classes cancelled because of a lack of adequate enrolment, despite schedules arranged for the convenience of industrially-employed engineers. Somewhat better success was achieved when lectures were offered at an industrial site (e.g., Waterloo at Sarnia). These experiences are consistent with those of engineering schools in the United States. There, in an attempt to improve the situation several schools have developed part-time programs based on a closed-circuit television talk-back system, in locations where large science-based industries operate. The industrial part-time graduate students participate in regular lectures but in their own lecture rooms on the plant site, by means of cable contact with the university lecture room. Thus, these students take the same lectures and write the same examinations as the full-time students. At Stanford University, where such a system has been in use for three years, we found general enthusiasm for the scheme. Records show the academic performance of industrial groups to be almost identical with that of students on campus.

Such systems are expensive, as indicated in Appendix C. However, they are particularly attractive where the engineering school is surrounded by "high technology" industry. In Ontario, the Ottawa region would be an ideal area for such an experiment, with its two engineering schools less than four miles apart. Ten miles to the west, at Shirley Bay, is Bell-Northern Research, the largest industrial laboratory in Canada, and the Federal Communications Research Centre. In addition, there are the excellent laboratories of the National Research Council, the Defence Research Board, the Department of Agriculture, and the Department of Energy, Mines and Resources. The study group recommends that:

(4:1) a talk-back television network in Ottawa be thoroughly explored.

If it proves to be impracticable there, probably it will not be feasible elsewhere in the province.

A general impression was gained that the sharing of research facilities is not yet well devel-

[3]*Chemistry in Canada*, Summer 1970, p. 20.

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oped, even though the idea is attractive — it brings staff and students together while at the same time offering the possibility of considerable economies. Much could be gained by making joint applications for negotiated development grants to acquire major equipment items. As evidence that such schemes do work, there is the 220 MHz nuclear magnetic resonance spectrometer, administered jointly by McMaster and Toronto and operated at Sheridan Park by the Ontario Research Foundation under contract with the National Research Council.

Recently, there have been expressions of concern over the restriction on public disclosure of the results of certain graduate research in order to protect the proprietary information of a sponsor. Such cases are rare and, of course, completely antithetical to the idea of graduate education. The student, at any stage of his research, must be free to discuss results with his colleagues, either in the seminar room, or in an appropriate journal. No other practice should be contemplated, and when classified work is undertaken it must not form part of the academic requirement of a graduate student. The graduate thesis should become a public document.

It is important that this study on graduate engineering education does not stand alone. Some of the concern expressed in this report will be applicable to graduate work in the sciences, the humanities, and the social sciences. Indeed we recommend that:

(4:2) a report be prepared for Ontario similar to that prepared by Allen M. Cartter,[4] dealing with graduate education in the United States.

Such a document, updated at regular intervals, would provide a comparative appraisal of the aims and quality of graduate education in the Ontario universities.

[4]Allan M. Cartter, Vice-President, American Council on Education. *An Assessment of Quality in Graduate Education*, a study for Commission on Plans and Objectives for Higher Education, American Council on Education. (Washington, D.C., 1966).

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5

RESEARCH

The pace of engineering research in Ontario began to accelerate in 1958, for two principal reasons:

(1) Seven additional engineering schools were taking shape, in anticipation of a rapid increase in undergraduate enrolment (Carleton, Guelph, McMaster, Ottawa, Waterloo, Western and Windsor). This expansion in engineering education necessitated a vigorous recruitment of faculty, which meant that in little more than a decade the number of university research directors increased eightfold.

(2) Most engineering deans were convinced there would be a rapid evolution of "high technology" industry in the 1960s — an assumption based on national needs and the developments in other countries. The result of such a swing into secondary and tertiary industry would be prospects of employment for large numbers of research and develop- personnel, many of whom would be educated in research-based programs.

An attempt has been made to provide a visual impression of the extent and intensity of engineering research in Ontario (Fig. 5-1). In this illustration, the fields of research endeavour have been listed under 45 headings, consistent with the classifications used by the Science Secretariat. The number of professors identifying a given category as their major research interest has been used as an indication of intensity of effort in a given field. We recognize that this is an imperfect criterion, because it contains no value judgment as to the quality of work being done by a given man or at a given institution. Thus no more should be read into Figure 5-1 than is intended — a measure of the amount of work under way. The shortest bars represent three or fewer principal investigators, the

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Figure 5-1 — ENGINEERING RESEARCH IN ONTARIO UNIVERSITIES

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medium-size bars denote groups of three to eight professors, and the largest bars, groups of more than eight. Thus, the density of the horizontal lines gives an impression of the extent of activity in a given area of research, while the density of the vertical columns gives an idea of the activity in a given institution. A more detailed description of engineering research programs is to be found later in this chapter in Tables 5-1, 5-2 and 5-3 and in Appendix D.

These summaries show the research program in Ontario as broad in scope, significant in total effort, and representative of large investment both in facilities and in operating expenses. For these reasons an attempt will be made to answer the following questions:

(1) Is the research component of graduate education providing suitable training for the graduate student?

(2) To what extent should engineering research in the universities be "mission-oriented"? Is the nature of the research being executed appropriate to the needs of our society and our economy?

(3) How might better university/industry cooperation be achieved?

(4) Is full advantage being taken of the opportunities for inter-university cooperation?

(5) Is the annual expenditure on engineering research in universities appropriate in the light of other needs?

(6) Is a reasonable and proper balance being struck among the three areas of teaching, research and consulting?

RESEARCH AS AN ELEMENT OF EDUCATION

Research in the engineering schools of Ontario is carried out by five classes of investigators: senior undergraduates, candidates for the master's and the Ph.D. degrees, post-doctoral fellows and professors. The involvement of undergraduates has been included here because of its importance in arousing the enthusiasm of the student, rather than for any contribution that might be made to advance technology.

Some of the most imaginative educational experiments have developed around the involvement of senior students as members of a team investigating industrial problems. Such problems may take the form of process simulation, optimization, design or operations research, and usually they are attacked by a student team, strongly supported by a group of professors and industrial engineers. It is in this area that the most significant industry/university cooperation has occurred. The enthusiasm of students for these projects can best be demonstrated by their heavy commitments of time and by the uniformly favourable response recorded at the end of each project. They represent a substantial commitment on the part of faculty, which seems fully repaid by the results. It is clear that this kind of early research experience should not only be continued but be emulated in those schools that do not have such schemes.

Most faculties of engineering have two types of program leading to a master's degree: research-intensive and course-intensive. The first has the traditional proportions of courses (2½ to 3½) to research experience (about 9-10 months of directed research), while the second has a heavier requirement of graduate courses (3½ to 5) with less time spent on research (a maximum of 6 months). The average period needed to complete the requirements for the degree is about 17 months. In general, students intending to proceed to the Ph.D. elect the former of these programs while those intending to finish with a master's degree choose the latter.

In Canada, standards for the master's degree have been kept high and it is well regarded by industrial employers. The reason for this esteem is that the graduate has had an extra year of course work, rather than on the anticipated value of an introduction to research strategies and techniques. For this reason, the proportions of students electing the course-intensive program should increase, especially if admission to Ph.D. programs is curtailed. Research performed by candidates for a master's degree in engineering generally seems to be of more significance in its context than similar effort in the pure sciences, if the proportion that reaches publication is a reliable indicator. Probably a reason for this is that so much of speculative engineering research is at the level of master's work where risk of failure will not have the disastrous impact on the student that can be the consequence of a fruitless Ph.D. research project. It is ironic that because of this concern for the student, the real ground-breaking is done by the least experienced, while the more senior students tend to address themselves to problems whose outcomes are relatively predictable. The criteria of assessment for engineering research theses to a large extent have been inherited from physics and chemistry, and no doubt it is time to study these criteria in the light of modern engineering. The Ph.D. degree traditionally involves a thesis of an analytical nature, while much of modern engineering innovation is in the area of synthesis, and this really is not research in the accepted sense of that term. Very few schools have programs of any kind in which a graduate degree is awarded for original design, as opposed to original research. It is for these reasons that the study group recommends that:

(5:1) The criteria of acceptability of graduate degrees in engineering should be recast in order that a thesis based on design or systems synthesis may be suitably assessed. This could involve the establishment of a new degree at the doctorate level.

There is little sign that the research component of graduate education is inadequate, and many instances have been observed where the training is of a superior nature. As proof, one can cite the generally high calibre of the Canadian engineering research journals, the ready acceptance of engineering research papers for publication in foreign journals and the distinction being achieved by Ontario graduates in domestic and foreign professional employment. A widespread concern has been voiced over the general lack of industrial or "beyond the cloister" experience of the teaching faculty, a deficiency that is said to affect the quality of both undergraduate and graduate programs. The main impact of such a deficiency on research activity appears to be on the relevancy of research projects, rather than on the quality of their direction or of the total educational experience. A study of the careers of members of engineering faculties shows a larger proportion of teachers with substantial professional background outside the university than seems generally to be appreciated. Nonetheless, as a result of vigorous recruitment in the 1958-68 period, there still are many young professors who come directly from graduate school. This pattern has provided justification for the contention that too often a professor's research is no more than an extrapolation of thesis material that has originated in the mind of his research director. In addition, the candidate for the master's degree, or the doctorate, often is exposed to so narrow an educational experience that he graduates without a proper awareness of the scope of his field of activity and soons finds himself to be less versatile than is desirable and necessary. However, this decade can provide time for consolidation when university/industry cooperation almost certainly will intensify and improve, giving members of engineering faculties an opportunity to acquire professional experience beyond the confines of the campus. Our concern is not so much that good research strategy and technique is not being taught but rather that the choice of problem should be topical.

RELEVANCE OF UNIVERSITY ENGINEERING RESEARCH

There has been a tendency over the past two decades for the topics of engineering doctoral theses to bear a stronger resemblance to physics than to engineering. This pattern is not peculiar to Ontario, or even to Canada, and one reason for it is the short space of time in which universities have been engaged in engineering research, as compared to developments in the pure sciences.

World War II provided dramatic examples of the power of basic science. After it was over, engineering educators began to enrich their curricula with more science and mathematics, hoping to turn out graduates more capable of bridging the gap between discovery and its practical application. In the university research laboratories of Canada, the majority of projects have been financed by grants from the National Research Council, whose committees were accustomed to allocating support to individuals for projects in the areas of pure science and who gave the appearance of having little knowledge of engineering research, or of the rapidly-growing resource of engineering academic personnel. It was learned that the more closely an engineering proposal resembled one in pure chemistry or physics, the greater was the chance of receiving adequate funds. This pattern has been changed, due in large part to the vigorous and vociferous activity of the National Committee of Deans of Engineering and Applied Science. But the memory lingers on, and in our graduate research laboratories there continues to be a disproportionately large amount of analysis, compared to the rather modest activity in synthesis — the real essence of engineering.

Three influences are at work that should redress this imbalance. The first is the position taken by the Science Council of Canada, in coming out strongly on the side of "mission-oriented" research — research with a foreseeable impact on problems of special relevance to Canada. The second is the adoption by the National Research Council of a more pragmatic role, which now takes into account the large task force of engineering research directors and graduate students. Finally, there is the industry/university interaction, which is exhibiting slow but reassuring growth as mutual confidence develops. It is becoming more widely appreciated that there cannot be a single research policy for science and engineering. Scientific research should have as its aim the contribution to knowledge, while the motivation for engineering research must be the application of known principles to the improvement of the quality of life. Traditionally, support for research has been based on confidence in the individual investigator, and this is appropriate for scientific research. Engineering research demands project support; now, this is available as negotiated development grants.

In several areas of engineering research there are manifestations of an increase in activity undertaken in response to social needs. At the University of Western Ontario a good beginning has been made in the interdisciplinary area of bio-engineering, in structural aerodynamics and in electrostatics. Waterloo has a vigorous effort under way in management science and transportation, while Guelph is quite properly continuing to emphasize agricultural engineering. At the University of Toronto, the Institute for Aerospace Studies has earned for itself a fine international reputation, the industrial engineering department is widely known for its involvement in operations research, and real distinction is being achieved in bio-medical electronics. McMaster has a growing reputation in the area of industrial simulation and optimization, its Institute for Materials Research is well established, and there is a new graduate program in production engineering. At Queen's, the program in mineral engineering continues to grow, while a new Institute of Guided Ground Transport has found substantial financial backing. It is encouraging to note that this list has no disturbing redundancies – with such a distribution of interest the prospect is good for building on strength. It is a trend that should be followed, in order that a pattern may be developed that avoids any duplication of effort.

At this point it is appropriate to try and identify areas of endeavour that appear to be receiving too little attention when one considers the social needs of this decade. Certainly, a growing proportion of engineers should devote their careers to the reclamation and proper maintenance of our environment. Now that most engineering schools are developing programs in some aspect of ecological engineering, a conscious attempt should be made to coordinate efforts and thus ensure that they are complementary.

One area in which engineers have achieved distinction is the development of techniques of analysis and simulation of complex, interacting, articulated systems. Originally, these systems were physical in nature – processes, circuits and vehicles. As techniques improved, studies were undertaken of the collation and analysis of information, computation and decision-making; and the interface between technological and social systems was crossed.

At the present time there is considerable scope for engineering research in areas which are particularly susceptible to the techniques of systems analysis and synthesis, such as:

(1) Urban planning and engineering.

(2) Building systems engineering, involving construction strategies, air handling, materials and personnel logistics.

(3) Design of airports and the ground transportation systems for the air industry. Canada's federal transportation mandate offers a favourable environment for this expertise to become an international commodity.

(4) Studies in the health care delivery systems of Ontario.

While it may not be feasible to cover all possible research areas, there are several others which appear to offer a particular opportunity at this time. For example:

(1) Instrumentation (including avionics) could be an important area of specialization in Ontario.[1]

(2) Illumination and acoustics. These are neglected areas: there is virtually no illumination research under way, and the problems created by acoustic pollution require immediate study.

(3) Cost and value engineering (including maintainability, reliability, quality control). Many industries require this type of expertise more urgently than technological help.

The study group has concluded that while a disproportionate amount of analytical research continues to be carried on in the Ontario engineering schools, an orientation towards social need is under way. As yet, there is no serious overlap of effort, but care must be exercised to prevent this from occurring. To date, direct industrial interaction with the engineering research programs has been rather minor in scope, but it does show signs of increasing.

INDUSTRIAL INVOLVEMENT IN UNIVERSITY ENGINEERING RESEARCH

The academic community is far from unanimous in the belief that their work should involve a direct outreach into society. Many still hold

[1] J. J. Green, *Aeronautics: Highway to the Future*, Special Study No. 12, Science Council of Canada, 1970, p. 90.

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firmly to the tenet that the university's role is to educate and to add to the world's store of knowledge, leaving the area of action to governments. The proponents of this viewpoint contend that such an aloof position is essential to the maintenance of the academic integrity of the institution. Those in the opposite camp point out that within our universities there is a large and diverse pool of knowledge and expertise accumulated at public expense, and that such institutions represent a unique resource for the assessment of social needs and the development of techniques to satisfy them. Most engineering faculty members appear to share the view that there is an obligation to use these resources for direct involvement in the larger community. Weisskopf and Smith have taken this stand:

> In the past, the universities have educated. The governments have acted. This complete division is no longer appropriate. Civilization has become so complex and its problems so enormous that the universities must be willing to a considerable extent to take on missions. There is simply not time to give out basic research data and hope that it will be intelligently applied. The university must assume a portion of the leadership in directing itself to specific problems.[2]

Since engineering must be the bridge between science and society, it is appropriate to look for university/industry interaction through the medium of the engineering school.[3] In Canada, despite a prodigious outpouring of rhetoric on the virtues of such an alliance, the results have been modest in the extreme. Today, university/government interaction is flourishing, as are the incentive programs provided by government to stimulate industrial innovation. It is the third side of the triangle that remains to be drawn with a firm hand. Even mature organizations such as the Institute for Aerospace Studies derive only token support from industry.[4]

It is inappropriate here to make a detailed appraisal of the failure to achieve vigorous cooperation in research between engineering faculties and industry. One of its symptoms has been the frequent deterioration of cooperative activity into a patron/mendicant relationship, with the university invariably cast in the role of mendicant. Recently, however, several schools have discovered they can achieve successful liaison through the medium of contracted research: a system that works well because the ground rules are easily understood. Three universities — McMaster, Waterloo, and Windsor — have established Industrial Research Institutes to carry out industrial research contracts, while other faculties of engineering have developed research companies, such as Chemical Engineering Research Consultants at the University of Toronto. The Industrial Research Institutes received seed money from the federal government, as well as financial support from university budgets. Other universities have applied for federal support to develop similar institutes.

This activity brings with it such special problems as the following:

(1) Local resistance on campus. There will be those within the campus who express a real concern over the fear that contract research distracts professors from their primary duties and may depreciate the quality of engineering research programs.

(2) The necessity of developing faculty confidence. It takes time for faculty members to decide on the admissibility of working within the institute rather than as a private consultant. Conversely, as the scope of activity develops, the Institute needs time to identify those faculty members who, as consultants, will be skilful, reliable and punctual.

(3) Resistance by the university community on the ground that restrictions relating to publication cannot be tolerated. A rule for such institutes must be that graduate students are not employed on projects of a proprietary nature, if the work is to form part of the requirement for their degree.

(4) Resistance by the Ontario Research Foundation on the grounds of direct competition. The validity of this concern depends on whether or not the university does have a role of service beyond those of teaching and research.

(5) Concern by private consultants based on the fear of subsidized competition. Care should be exercised to undertake projects of a special character for which the university has a special competence.

[2]Victor Weisskopf and Gregory Smith, *Public Policy, Public Opinion, and the University*, reported in the Review Panel of the Special Laboratories of the Massachusetts Institute of Technology.

[3]Dr. Fred Terman underlined this opinion in his report *Engineering Education in New York*, published in 1969: "Experience at M.I.T., Stanford, Cal. Tech., and elsewhere shows that the largest part of the coupling that exists between a university and its surrounding industrial environment normally comes through the engineering rather than the science departments. This is not to imply that science departments make no contribution, or that science isn't important to technology-oriented industry. Rather, it simply recognizes the fact that it is ordinarily the engineer who transforms a raw idea of science or technology into a product that is useful, practical and reliable. The engineer is thus the person most frequently at the point of contact between education and industry."

[4]Green, *Aeronautics: Highway to the Future*.

(6) General concern about the propriety of professors acting as consultants. This is relevant to the general policy relating to consulting by university faculty, and is discussed in the final section of this chapter.

Despite these concerns, industrial research contracts worth more than $3 million were negotiated and executed in the Ontario engineering schools over the period 1967-1970. This represents a sharp increase in such activity, and indicates that the contracted research project may be a vehicle for successful cooperation. Now that this scheme is proving to be effective, it is reasonable to anticipate that university outreach will grow in volume and in scope. The importance of such activity is brought to the fore in periods of financial stringency such as the one being experienced at the present time, when the size of industrial research and development staffs are held to existing levels.

INTER-UNIVERSITY COOPERATION

A good deal of informal cooperation among universities has taken place in the sharing of expensive research facilities. Arrangements such as the one developed by Toronto and McMaster for the operation of a high-frequency nuclear magnetic resonance spectrometer have worked admirably and should be emulated where other neighbouring schools have coincident requirements.

There seems to be less cooperation in the development of research programs where each participating campus could fufil a specific role. One such joint effort is the recent proposal for a negotiated development grant for communications research to be undertaken at Carleton and Queen's — although one wonders at the exclusion of the University of Ottawa.

In considering the opportunities for cooperation in research activity, the study group was struck by the unique situation that exists in the Ottawa area where two engineering faculties are separated by a distance of less than four miles, each below "critical size", yet each with its particular character. Surrounding them is the most concentrated research effort in the country — the National Research Council, Department of Energy, Mines and Resources, Defence Research Board, Department of Agriculture and Bell-Northern Research. In Chapter 4 we have suggested that it is a natural locale for a talk-back television system as an experiment in part-time graduate studies. Furthermore, we shall recommend that the combined educational role of these two schools should be that of Information Systems Engineering which could include such a broad spectrum of activity as instrumentation and control, microwave systems, remote sensing, communication, optical engineering, avionics and antenna systems. It is a natural extrapolation to recommend that the research role of these neighbouring faculties should be a joint one, since it provides a unique opportunity to exploit the coalescence of skills and faculties.

ENGINEERING RESEARCH EXPENDITURE

It is difficult to form a reasoned viewpoint on whether or not research expenditure is appropriate to the needs of the economy, and whether present financial commitment to research is justifiable when considered as a proportion of the total expenditure on engineering education. It has come to be recognized that comparisons with other countries are not very informative, and that the gross national product is a poor indicator of the goals for an industrial nation. Probably one is not even justified in attempting to draw conclusions from the expenditures in the different areas of engineering research, since some forms of such endeavour are much more expensive than others. Today, more money is available for engineering research than at any time in the past. Indeed, sufficient funding is available to look after all of the really worthwhile engineering research in the universities of the province, although its distribution may be somewhat uneven.

Table 5-1 represents the total research grants made by all agencies for the support of projects and the salaries of some of the research personnel (graduate students, post-doctoral fellows, and technicians).

Table 5-1

RESEARCH GRANTS IN ONTARIO FACULTIES OF ENGINEERING

University	Total Grants ($000) 1968-69	1969-70	Two-year-Total
Carleton	194	229	423
Guelph	210	210	420
McMaster	774	1,153	1,927
Ottawa	209	261	470
Queen's	765	615	1,380
Toronto	2,150	2,541	4,691
Waterloo	1,333	1,782	3,115
Western	517	391	908
Windsor	294	391	685
	6,446	7,573	14,019

The figures given above do not represent the full cost of research programs, for most universities make substantial budget allocations for special research projects and for the maintenance of graduate student stipends. Income from the Province of Ontario, based upon the formula for graduate student enrolment in engineering, was $10,166,000 for 1968-69 and approximately $11,500,000 in 1969-70. Thus, a rough estimate of the cost of graduate studies and research in engineering in the last two complete academic years was $16.6 million and $19.1 million respectively.

The most important activity in our graduate schools should be the extension of the skills of students — assuming, of course, that they will have the opportunity to practise these skills. Over the past five years, substantial numbers of master's degrees have been awarded, while the number of doctorates doubled between 1965 and 1969. (Appendix B, Tables B-8, B-9). At the present time, a large number of Ph.D. candidates are enrolled, which means a rising number of Ph.D. graduates through 1973. It is because of the prospect of a considerable over-supply in matching Ph.D. graduates with appropriate employment opportunities that we have recommended a curtailment in programs at the doctoral level.

An indication of the yields from research programs is given in Tables 5-2 and 5-3, which summarize these efforts on the basis of both faculty and research subject. The average rate of publication per professor is a little over one reviewed paper a year, although it does vary widely from institution to institution, from a single publication every two years to two papers a year. It would be hazardous to draw any conclusions from this difference, except to suspect that the lowest figure reflects an underdeveloped research program, while the highest figure may indicate that the undergraduate program is receiving insufficient attention.

Though filing of patents is not a primary aim for a faculty of engineering, it does give some indication of the relevance of research to industry. Over the past two years the number of patents granted has shown an increase, possibly as the result of a swing towards mission-oriented research. The present total for all schools in Ontario is about 50 patents a year. Our data do not include an estimate of the income derived from them.

Probably, it is impossible to decide whether or not the present intensity of research is appropriate to the Ontario university scene — such a cost/benefit analysis is too sophisticated for this study. Indeed, it is unlikely that such an evaluation could be applied with any confidence. However, our recommended curtailment of Ph.D. programs should not be interpreted as a suggestion that university research effort is too extensive; it is based solely on the supply of students and the demand for their services following graduation. The present scale of research effort appears to be appropriate, particularly in view of industrial retrenchment. This level should be maintained by the natural growth of enrolment in master's programs, and by making greater use of technicians and post-doctoral fellows. Therefore, some of the savings realized from curtailment of doctoral studies must be made available for these other purposes.

BALANCE OF EFFORT: TEACHING, RESEARCH AND CONSULTING

The essence of engineering is the integration of the principles of science into the solution of practical problems confronting our society. Members of such faculties have a particular obligation to keep abreast of the changing scene and of techniques being developed by industry, in addition to their traditional responsibilities for teaching and research. This can be accomplished by sabbaticals in industry, by setting up a satellite campus on an industrial site and by providing professional consultation. To date, industrial sabbaticals have been relatively rare, although the reports on them are enthusiastic. In order to stimulate this kind of interchange, the National Research Council is giving consideration to implementing Senior Industrial Fellowships tenable in industry, where the holder need not restrict his work to research and development activity. The intent is to extend university/industry interaction beyond the laboratory or pilot plant.

Since the experiment of a satellite campus has yet to be tried in Ontario, consulting activity is still the most important vehicle for university/industry interaction. All universities should have definite regulations on consulting by faculty members, and most campuses in Ontario already do. In the absence of a clearly stated policy, the academic program can become relegated to a position of secondary importance.

There are three long-standing criticisms of the practice of consulting by university faculty members. The first has been noted above; the second is the realization that an individual may derive extra income by diverting some of his effort away from the specific tasks for which he was engaged. Third is the concern that a professor may be providing unfair competition for the private consultant who must sustain the full cost of overhead in carrying on his practice. While such criticisms are valid, nevertheless there are significant advantages to be gained for a university from encouraging faculty consulting. An intimate knowledge of current industrial practice adds to the teacher's sense of topicality. There are many examples (although rare in Canada) of entire industries which have been established and are flourishing as a result of industry/professor interaction. At the present stage of Canada's technological development, with the preponderance of "high technologists" working in the universities, such institutions provide industry with a skill resource that would otherwise not be attainable. For these reasons, we believe the engineering faculties of Ontario should encourage faculty consulting, within the terms of an acceptable policy. Usually this specifies that 40 to 50 days should be the maximum time devoted to consulting in any one year. The study group favours the lower figure.

The evolution of the schools of engineering has taken place during a period of vigorous academic expansion and technological change. This has resulted in heavy emphasis on the research skills of university teachers, so that by 1970 the total research effort is substantial, quite appropriate in size to the extent and nature of the system. However, although there is room for concern that too much of this research still lacks relevance to national needs, present funding is sufficient to finance all of the worthwhile work now under way. As research programs mature, centres of excellence have begun to appear, each with special reference to certain facets of Canadian needs, and industrial involvement is developing, albeit still too slowly. As can be seen from Appendix E, the assembly of capital facilities and equipment has been substantial, so there is an adequate base from which to proceed into the 1970s.

This build-up of research capability has been accomplished in part at the expense of the undergraduate program. Now that it has achieved critical size, attention should be directed toward experiments in educational technology and innovation in undergraduate education. Research can assume its appropriate significance as an integral part of the system.

Table 5-2

AREAS OF RESEARCH EFFORT IN ONTARIO FACULTIES OF ENGINEERING

UNIVERSITY	No. of Faculty (1969-70)	Graduate Students (1969-70) Full-time Equivalent	Master's Degrees 1967-69 1968-69	Ph.D. Degrees 1967-68 1968-69	Research Support 1969-70 ($000)	Publications 1967-68 1968-69	Patents 1967-68 1968-69
1. Carleton	35	115	27	6	229	35	3
2. Guelph	30	23	28	1	210	30	2
3. McMaster	61	184	75	16	1,153	260	6
4. Ottawa	39	156	34	9	261	103	3
5. Queen's	92	168	58	11	615	124	6
6. Toronto	200	625	294	57	2,541	595	58
7. Waterloo	164	456	202	42	1,784	473	3
8. Western	39	79	45	1	391	72	12
9. Windsor	48	87	49	3	389	65	3
TOTALS	708	1,893	812	146	7,573	1,757	96

Table 5-3

ENGINEERING RESEARCH IN ONTARIO UNIVERSITIES

CATEGORY	(1969-70) No. of Grad. Students	Master's Degrees 1967-68 1968-69	Ph.D. Degrees 1967-68 1968-69	Research Support 1969-70 ($000)	Publications 1967-68 1968-69	Patents 1967-68 1968-69
1. Acoustics	4	6	0	5	1	0
2. Aerodynamics	124	51	11	879	82	4
3. Antennas	11	3	1	27	5	0
4. Applied Physical Chemistry (misc.)	35	10	9	204	46	9
5. Bio-engineering	27.5	21	2	88	39	1
6. Bio-medical Engineering	29	11	3	120	28	2
7. Ceramics	7	0	0	30	19	0
8. Chemical Kinetics and Reactor Design	46	12	4	159	60	3
9. Circuit Theory	0	1	0	5	5	0
10. Communications Technology	58.5	30	3	203	55	5
11. Computer Hardware	61	24	3	123	19	2
12. Control Systems	99	53	3	206	78	0
13. Corrosion, Electrochemistry	3	1	0	3	1	0
14. Design and Production	33	11	1	92	24	1
15. Dynamics and Stability	19	6	1	58	18	0
16. Ecological Engineering	72	42	1	450	54	6
17. Electrostatics	11	7	1	85	8	7
18. Energy Conversion	15	5	1	57	9	0
19. Engineering Management						
20. Extractive Metallurgy	62	23	6	461	106	5
21. Fluid Dynamics	78	36	15	407	87	5
22. Geotechnical	58	34	6	242	56	10
23. Heat and Mass Transfer	82	30	8	279	89	1
24. Hydrology	50	21	1	110	32	0
25. Information Systems	4.3	2	0	4	0	0
26. Materials Handling	39	14	3	181	46	2
27. Material Research (general)	35.2	17	3	175	61	3
28. Microwaves						
29. Mining and Mineral Processing	21.5	11	0	50	18	0
30. Nuclear Engineering	10	0	0	35	16	0
31. Ocean Engineering	16	5	3	100	16	1
32. Operations Research	34.5	15	4	69	22	0
33. Optics	3	0	0	42	2	0
34. Physical Metallurgy	58.5	30	5	528	148	6
35. Plasma Technology	19	8	5	139	32	2
36. Polymer Technology	38	14	1	225	92	9
37. Power Transmission and Distribution	66.2	27	7	195	65	6
38. Process Design and Simulation	24	10	4	120	61	0
39. Solid Body and Continuum Mechanics	158	45.1	3	284	47	0
40. Solid State	64	24	2	226	52	3
41. Stress Analysis and Structural Design	172	91	17	462	95	0
42. Surveying and Mapping	8	5	0	65	6	1
43. Systems Analysis and Design	42	26	9	81.5	22	1
44. Thermodynamics	49.5	12	4	210	39	0
45. Transportation Systems	45.3	17	2	156	21	0
Totals[a]	1,893	811	152	7,640.5	1,822	95

a There are discrepancies between Tables 5-2 and 5-3, presumably because of overlapping fields of research interest.

6

THE PROFESSORS

In 1969-70, the 721 faculty members of engineering schools in the provincially-assisted universities were distributed as follows:

Table 6-1

FACULTY MEMBERS

University	Number
Carleton	35*
Guelph	30
Lakehead	9
Laurentian	4
McMaster	61
Ottawa	39
Queen's	92
Toronto	200
Waterloo	164
Western	39
Windsor	48

*Exclusive of part-time faculty.

Since it is impossible to compose a verbal composite picture of this group, the relevant information on our professors of engineering is presented in histogram form in Appendix F. It shows that 519 (72%) of these university teachers hold Ph.D. degrees, 144 (20%) hold master's degrees, and 58 (8%) hold only bachelor's degrees. McMaster has the highest proportion of faculty with doctoral degrees (92%) and Guelph the lowest at 25%. An examination of the disciplines shows that metallurgy and materials sciences have the highest proportions of faculty holding Ph.D.'s.

Even though nine schools are relatively new, the age distribution of the group is broader than might be expected. The median is 38 years, with metallurgical engineering having the highest average of 43 years, and civil engineering the lowest, 33 years.

The country of birth for the engineering faculty is as follows:

Canada	— 48%
United States	— 4
United Kingdom	— 16
Other	— 32

The two northern schools, Laurentian and Lakehead, have the highest proportion of Canadian-born faculty, with 75% and 66% respectively, while Ottawa has the lowest, with 28%.

An indication of the development of Canadian engineering education is given by the proportions of the origins of faculty degrees:

University of Toronto	— 21%
Other Canadian Universities	— 22
United States	— 26
United Kingdom	— 23
Other	— 8

A possible reason for the sameness of the Ontario engineering schools is that the University of Toronto has educated such a large percentage of the province's engineering professors. Guelph has the highest proportion of Canadian-educated professors (56%), while Western has the lowest (33%). The highest proportion of Canadian advanced degrees is in chemical engineering (43%), and the lowest in civil engineering (35%).

As mentioned earlier in this report (pages 21 and 23), there have been frequent expressions of concern over the background of professional experience beyond the university. This is given for the province as a whole in Table 6-2.

Table 6-2

YEARS OF PROFESSIONAL PRACTICE[a] AMONG MEMBERS OF ONTARIO FACULTIES OF ENGINEERING

Years	% of Total Faculty Population	
0	15	58%
1	8	
2	12	
3	8	
4	9	
5	6	
6-10	18	42%
11-15	13	
16-20	5	
Over 20	6	

a Industry or other, not including academic or teaching experience

The extremes in this compilation are represented by the University of Toronto, where 45.5% of the faculty have more than five years' industrial experience, and McMaster, where the corresponding figure is 32.8%.

It is most important that considerable teaching expertise accumulate within the system. The average figures for Ontario at the present time are shown in Table 6-3.

Table 6-3

YEARS OF TEACHING EXPERIENCE IN ONTARIO FACULTIES OF ENGINEERING

Years	% of Total Faculty Population	
0	1	43%
1	7	
2	8	
3	11	
4	9	
5	7	
6-10	27	57%
11-15	16	
16-20	6	
Over 20	8	

It can be seen that the range of teaching experience is wide — at McMaster 65.5% have more than five years, while for Carleton the corresponding figure is only 31.5%, with the provincial median being 7 years.

Faculty mobility appears to be fairly high, 61% of the professors having been members of their present faculty for less than five years. At Toronto 50% of the faculty have more than five years' service there, while at Carleton 83% have been there fewer than five years.

As has been noted elsewhere in this report, the educational process is closely linked with the professional aspects of engineering. Much of the individual's professional indoctrination begins in university, and therefore it is of interest to see the extent to which faculty members are registered professional engineers. The figures show a wide variation — from discipline to discipline and from university to university — as revealed in Table 6-4.

Table 6-4

PERCENTAGE OF FACULTY WHO ARE REGISTERED PROFESSIONAL ENGINEERS

Discipline	Provincial Average %	Highest	%	Lowest	%
Chemical	45	Toronto:	85	Western:	14
Civil	85	Windsor:	100	Ottawa:	75
Electrical	56	Western:	83	Waterloo:	38
Mechanical	60	Toronto:	78	Waterloo:	43
Metallurgical	47	Windsor:	80	McMaster:	20
Industrial	27	Toronto:	42	Windsor:	0

If registration as a professional engineer can be taken as an indication of professionalism, then Toronto has the highest involvement with 73% of its faculty on the roll. At the other end is Waterloo with only 46% registered. The provincial average is 59%. It does seem strange that industrial engineering is the one having the least professional involvement. The important aspects of professionalism — an acknowledgement of a code of professional ethics, the background of Canadian technological history and of Canadian technological environment — are not being treated in a serious fashion at most of the Ontario engineering schools. Few engineering calendars show the designation P.Eng. in listing members of faculty. While it is all but impossible to teach professional attitudes otherwise than by example, the surprisingly low proportion of faculty so registered does not present the best kind of professional image to the student.

With the exception of Carleton, there are few adjunct appointments of private consultants or of engineers from industry, although the reports are enthusiastic where it has been tried. The study group believes this practice should be extended and we adopt as our own the recommendation in a joint university/industry study completed recently in England:

(6:1) "We feel that both universities and industries should recognize this activity as part of the career structure of their senior staff, and joint appointments should be increased as far as possible. We would hope that in time there would be at least one joint appointment in each department, certainly in those relevant to industry."[1]

Now that an opportunity for consolidation is in prospect, it does seem appropriate that more attention be devoted to the development of teaching excellence on the part of members of faculty. If we are to enhance the educational experience of the undergraduate, more time must be devoted not to producing yet another isolated course,[2] but to a continuing program of relevant curricular design and pedagogical development.

[1]*Industry, Science and the Universities*, Confederation of British Industry, London, July 1970.

[2]"Some day soon, one of the Canadian universities will set up a course on the care and feeding of camels. And will the people who graduate in it go to the Middle East? Don't be silly; they'll just go to other Canadian universities and set up courses there on the care and feeding of camels. Graduates from these courses will go to teach the subject in high schools and community colleges. Eventually Canada will have 10,000 accredited camelologists, none of whom has ever seen a camel." Richard J. Needham in the Toronto *Globe and Mail*, November 17, 1970.

7

THE PROFESSION

The fundamental purpose of an engineering education is to prepare young people for entry into the profession. The relationship between the profession and educational institutions should be very close. Consequently, we have studied certain elements of the practice of engineering in order to develop recommendations related to universities concerning entrance into the profession, requalification and the accreditation of engineering programs.

ENGINEERING AND SOCIETY

A definition of engineering was set down for the first time in 1828 by the Institution of Civil Engineers in Great Britain. It was described as "the art of directing the great sources of power in nature for the use and convenience of man."[1] More recent definitions have replaced the phrase "use and convenience of man" with such words as "benefit of man", where the word "benefit" implies not only use and convenience, but also social responsibility.

[1]Charter of the Institution of Civil Engineers, 1828.

As we move into the 1970s, the profession of engineering finds itself in a vulnerable position brought on by the wave of social concern of young people, together with the accelerating erosion of our physical environment caused by a disregard for the consequences of technology. Today, engineering has an unappealing image for many young people as they turn from the physical to the social sciences or the humanities in a search for answers to questions about timeless values and the quality of life.

Engineering is regarded by many as a profession without a social conscience, but surely this is a paradox, since a profession cannot be worthy of the name if it has no social conscience. The interaction between engineering and society can be illustrated by a functional diagram (Fig. 7-1).

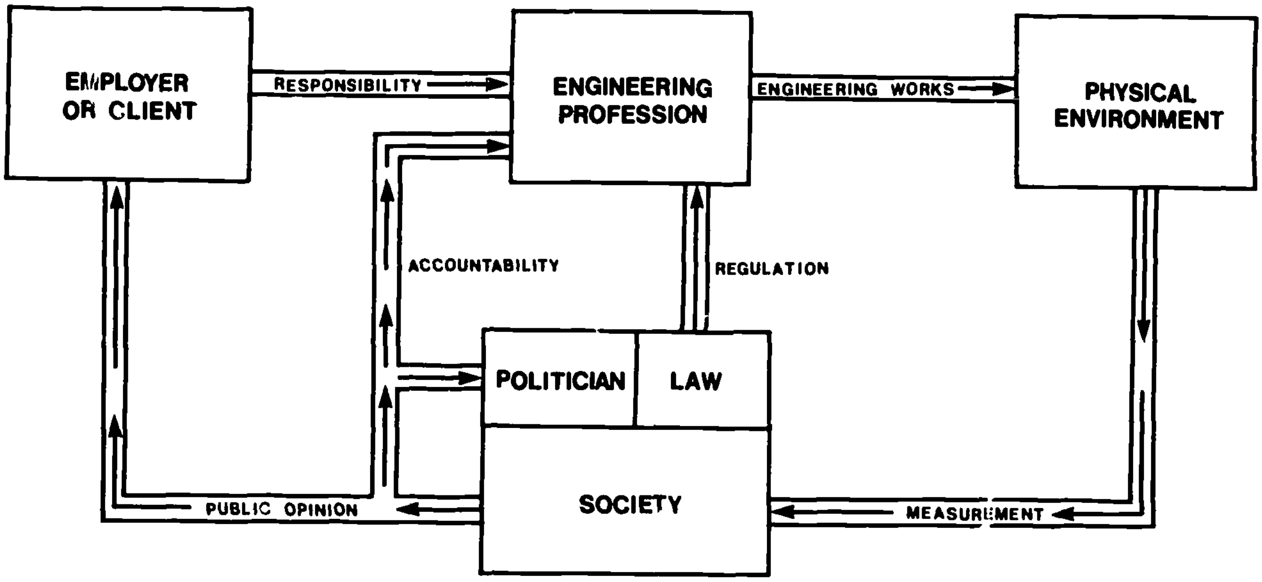

Figure 7-1 — THE ENGINEERING PROFESSION AND SOCIETY

The engineering profession is responsible to employers and clients for the creation, management or control of products and processes that influence and alter our physical environment. The result of its activity will be detected, measured and evaluated by society in the form of public opinion. It is in this way that society holds the profession, the politician and the employer or client accountable for the effects of their actions, good or bad, on the physical environment.

Engineering involves specialized knowledge and techniques, and because such activity affects the physical environment, the profession is regulated by law to protect the public against incompetence and fraud. In Ontario, as in the other provinces of Canada, licensing and regulating powers have been provided through an Act of the Legislature, to permit the profession to exercise its powers, and to provide remedies against incompetent or dishonest practitioners.[2] While no such Act is capable of regulating all engineering works, the public does hold the engineer accountable for socially undesirable action, and so it behooves the profession to minimize such action. Its public esteem, prestige and usefulness will vary according to how well its members perform in this closed loop system. It is for such reasons that engineering is being held accountable for the despoiling of our physical environment. Of course, every profession is similarly accountable for its own related environment — medicine for the environment of health care and law for the civil environment.

For the purposes of this study, the definition of engineering that will form the basis for many of the final recommendations is the following:

> "Engineering is a profession, responsible and accountable for man's physical environment, its management and control."

Such responsibility and accountability must be shared with others, and therefore the definition is equivocal and meant only to serve the purposes of this study.

ENTRANCE INTO THE PROFESSION

For many years, the demand for engineers in Ontario has outstripped the local supply, and approximately one-third of the members of the profession have received their education in other countries.

Many of these members graduated from institutions or programs that are not recognized in

[2] "The granting of self-government is a delegation of legislative and judicial functions and can only be justified as a safeguard to the public interest. The power is not conferred to give or reinforce a professional or occupational status." *Royal Commission Inquiry into Civil Rights.* (Toronto: Queen's Printer, 1968), Report No. 1., Vol. 3., p. 1162.

Ontario. Others, from Canada and abroad, while not possessing engineering degrees, have sought professional status on the basis of their experience and academic background acquired through self-study. A syllabus of entrance examinations was established for such individuals, which is deemed to be equivalent to the baccalaureate standard from an accredited university program. Each candidate is assessed, and a candidate's academic record may permit certain entrance examinations to be waived. Such a system permits persons unable to enter or complete university to be assessed objectively. It has provided a practical and just alternative for those who would be shut out on grounds other than failure to attain proper standards of competence.

In recent years, the files of the Association of Professional Engineers of Ontario (APEO) have contained approximately 4,000 such applicants at any given time. Each year, about 25% drop out, to be replaced by an approximately equal number. This examination procedure is operated annually by the APEO at many centres throughout Ontario, in other provinces and even outside Canada. In 1970, a total of 732 candidates wrote 1,746 papers. Only 3% actually satisfy the requirements for entering the profession, and in the main these are candidates possessing degrees from non-accredited institutions.

The extremely low number of successful candidates from the relatively large pool of applicants appears to confirm the conviction of academics that a university setting provides a better way to master a body of knowledge. One must conclude that a much higher success rate would result from the completion of a formal course of study.

Today, with universities spread throughout Ontario, it should be possible to offer undergraduate courses at times convenient for those employed full-time during normal working hours.[3] In the past, attempts to provide such classes have met with scant success because of a lack of numbers. The use of the new media, such as television, would ease the programming problem by making it possible for such classes to be held off-campus. Furthermore, a proposed new program for requalification should increase the size of classes in the more specialized subjects.

Initially, the syllabus must be equated to specific undergraduate programs, and the successful completion of such courses recognized as credit towards entry into the profession. University admission standards, which are in effect a preliminary screening, should lower the present attrition rate.

While this procedure is being developed, it will be necessary to continue with the APEO entrance examinations, but the numbers of candidates should decline as more and more individuals turn to part-time studies provided by the universities. When the number of such courses available amounts to a complete engineering program, then universities can offer a bachelor's degree to all candidates who successfully complete the syllabus. Under these circumstances, it would be practical for the profession to insist on an engineering bachelor's degree from a recognized university, together with the requisite experience as a graduate engineer-in-training as the minimum standard for professional registration.

It is recommended that:

(7:1) the universities introduce part-time undergraduate studies as an acceptable alternative path to a recognized bachelor's degree in engineering, and that when this scheme is fully operative, the present APEO examination system be terminated.

Thus, any candidate will continue to have a route into the profession that could be followed without excessive financial hardship. An APEO examination might still be required for special cases in locations outside Ontario.

In any such plan, appropriate recognition should be granted to the specialized three-year curriculum leading to a diploma in technology, offered by the CAATs. Elsewhere in this report (page 81), a case has been made for a two-year full-time post-diploma degree course in engineering. This would be made possible by altering the sequence of material to create a curriculum structured especially for CAAT diploma graduates. Similarly, university admission requirements for such students seeking entry into the profession through part-time studies should recognize certain material already covered in the CAAT diploma program. At the present time this is not done, and the diploma graduate usually enters at the level of the second year.

The above plan would place the universities in a monopolistic position in determining whether or not a candidate has the academic qualifications to enter the profession. However, the successful achievement of academic qualification should not be the only requirement for admission into the profession. It is suggested that the applicant should acquire the equivalent of two years of acceptable engineering experience as a graduate engineer-in-training, during which

[3]In 1970-71, the University of Toronto is offering part-time classes in its School of Extension for credit toward completion of the first year of engineering.

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period he would be exposed to an environment that encourages the development of professional conscience, responsibility, maturity and judgment. If the profession is to discharge its responsibility, then it must be satisfied that the applicant will enter professional practice having due regard for the public interest. Each graduate engineer-in-training should prepare a short, structured dissertation on his experience, which, if satisfactory, would entitle him to sit for a final examination in professional practice to be set and administered by the profession. In this way, universities would not be the sole arbiter, and the profession would be satisfied that all its members have developed an awareness of their responsibilities and obligations as practising engineers.

The recommended alterations in entrance requirements (page 7) will require the scheduling of "make-up classes" in the first year. If this is coupled with the recommendation in regard to part-time degree studies, a convincing case can be made for offering engineering classes during the summer months — a time when many high school teachers are in university. Hence, it provides an ideal opportunity to involve them in technology-related subjects. Concern has been expressed over the fact that engineering has not been getting its story across to the high schools. It would be necessary to create special classes in technology for such teachers, but the resulting long-term benefits to the profession and society are indisputable.

REQUALIFICATION

Since accountability is the hallmark of any profession, surely there is reason for insisting that its members maintain and enhance their ability to account to society for their actions. The dynamism of tomorrow's technology will soon render today's techniques obsolete. The half-life of the content of the present engineering curriculum is no more than five years,[4] and so there is a compelling need for the continuing education of the engineer, together with a requalification process. In this way assurance can be given to those served by the profession that it intends to fulfil its obligation to society.[5]

[4]Allen B. Rosenstein, *A Study of a Profession and Professional Education*, U.C.L.A.., School of Engineering and Applied Science. EDP 7-68, December 1968, Part II, p. II-11, Appendix A. (The half-life of a curriculum is that period of time during which one-half of the initial content of the program will change.)

[5]*Report of the Committee on the Healing Arts* (Toronto: Queen's Printer, 1970). Recommendations 11 and 12, Vol. II, p. 81 — a program for ensuing continuing competence where, perhaps every five years, every physician in Ontario would be required to submit a certificate stating he has maintained a satisfactory level of competence; and a recommendation that Ontario faculties of medicine develop such a program.

For engineering, as for the other professions, this requalification process should come as rapidly as possible. The profession's membership is large, with deeply rooted patterns and traditions. Thus we arrive at a major interface between profession and university in that the latter should play a significant role in any plan of requalification.

One could insist that all members, without any exceptions, must requalify at periodic intervals. However, it would be more practical to establish specialist categories within the profession for which requalification is required, and then gradually introduce limitations of practice within these categories. Members in the consulting sector should be the first to change because of their direct involvement with public works. Others would take a longer time and it may be that a whole new generation would join the profession before universal requalification became accepted as the normal pattern.

Traditionally, the success of an engineer has depended on his knowledge of the physical sciences, mathematics and technology. With this background, and with experience, he can be given responsibility for engineering works. However, we have maintained that the profession carries with it the requirement of accountability: to be aware of the social consequences of engineering works. For this, one must develop sensitivity towards social, psychological and political forces, and even aesthetics. The subjects dealing with such forces have formed the basis of the university arts curriculum, but here we are interested in them only insofar as they pertain to the professions. Dr. Allen Rosenstein calls this aspect of these subjects the "applied humanities".[6] For the engineer of tomorrow these will be as important and as necessary as his technical specialty. A lack of competence in either area will result in failure as a professional man or woman.

We will show (page 49) that the majority of engineers move into occupations that are associated with either the control or management of the physical environment, but accountability is common to both. Competence should be demonstrated along these lines, and this could form the basis for a structured requalification program. Control relates to occupations involving research, development, design or operation (i.e. technology and science); management implies competence in areas such as economics, accounting, finance, marketing, production, and the behavioural sciences. We recommend that:

[6]Rosenstein, *Study of a Profession*, II-11. See also W. H. Davenport and J. P. Frankel, *The Applied Humanities*, U.C.L.A. Department of Engineering, EDP 3-68, May 1968.

(7:2) periodic requalification (perhaps every five years) be initiated so as to require successful completion of a course of study in either control or management, or a combination of these two, together with a structured program in applied humanities.

The details are a matter for the profession to establish in close coordination with the educational community — principally the universities, but also the CAATs and the professional societies and associations.

The graduate material of but a few years ago now is being taught in undergraduate classes. This downward drift of new knowledge has always existed, but in recent years it has moved into the secondary and even primary schools. Therefore, the demands on the universities in response to a program of requalification will be felt at both the graduate and the undergraduate levels. Again, this raises the matter of part-time studies, class programming and television instruction. Part-time graduate studies in engineering are presently available in several universities, but the opportunity to do part-time work at the undergraduate level is virtually non-existent. Furthermore, the scheduling of classes to meet the needs of the practising engineer and aspiring entrants into the profession should create pressures to develop instruction by television at a more rapid rate, and could lead ultimately to the widespread use of electronic video recording. These matters should be the subject of a detailed study conducted jointly by the practising profession and the engineering schools.

The requalification of the engineering teacher poses a different problem. The requirement is not so much the need to acquire new knowledge in his chosen field, which is part of his regular academic duties, but rather the maintenance of a continuing awareness of the real world of engineering outside the university. Consulting and industrial sabbatical periods can be effective in achieving this aim, but a further opportunity exists. When a requalification program is under way, many of the classes could be in the form of open seminars so that there may be an exchange between senior engineers and the academic staff. In this way both groups benefit, and the teacher can gain a broader perspective on contemporary engineering practice.

Today practising engineers, particularly the employee sector, find themselves in a dynamic environment where occupational mobility becomes the only alternative to obsolescence and unemployment. Continuing education, reinforced by the requalification program, could remove the present barrier to mobility. Economic benefits, although not readily measurable, should be substantial, because this form of continuing education would have the effect of more closely matching manpower resources and manpower needs.

ACCREDITATION

In Ontario, as elsewhere in Canada, most young people enter the profession after the successful completion of a recognized engineering program in a university, followed by a specified period of time spent as a graduate engineer-in-training. Accreditation is the procedure whereby an engineering program, faculty and facilities are recognized by the profession. It was first introduced on a national scale in the United States in the early 1930s by the Engineering Council for Professional Development (ECPD). The impetus for accreditation at that time arose from a rapid proliferation of engineering schools with varying standards. It has gained steadily in prestige, so that today few institutions ignore it. The ECPD, which is not a licensing body, publishes a list of accredited curricula leading to first degrees as guidance for young people planning an engineering education in the United States.

In Canada, accreditation has only been conducted by the licensing bodies. While accreditation in the United States is for a stated period of time, in Canada, until very recently, accreditation has not been limited in this manner.

Accreditation in both countries involves several criteria, which entail aspects of both quality and character. These are:

(1) curriculum content and its relevance to engineering practice,

(2) teaching staff and teaching loads,

(3) physical facilities, including library,

(4) administrative practices and arrangements.

The Canadian Council of Professional Engineers, a national agency coordinating the eleven provincial and territorial constituent organizations, formed the Canadian Accreditation Board (CAB) in 1965. One of its stated objects is to "make a complete re-assessment of all accredited curricula at regular intervals to be established by the Board, but not exceeding five years". This in in sharp contrast to the traditional practices of the constituent organizations by which accreditation, once granted, was never repeated.

The Ontario Accreditation Committee of

APEO carries the responsibility for accrediting engineering programs to be recognized by APEO for registration purposes. This committee may be replaced by CAB, leaving a single national body to deal with accreditation.

There are four issues relating to accreditation, as they apply to engineering education and the recommendations of this report:

(1) accreditation of new programs being introduced in various universities,

(2) periodic accreditation of existing programs,

(3) accreditation of classes in continuing education programs designed to lead to registration.

(4) accreditation of classes and programs designed for requalification.

1. *Accreditation of New Programs*

Both the Ontario Department of University Affairs and the Committee of Presidents of Universities of Ontario (CPUO) are concerned about the proliferation of new programs. The Ontario Council of Graduate Studies (OCGS), an affiliate committee of CPUO, has developed an appraisal scheme for assessing the quality of new graduate programs proposed by Ontario universities. Similarly, appraisals are needed at the undergraduate level, not only to ensure quality, but also to control program proliferation and — it is hoped — to effect more of a match with the need for new curricula to meet changing manpower requirements. The most appropriate group to conduct such evaluations would be the Committee of Ontario Deans of Engineering (CODE). If CODE were to perform this function, and if CAB were represented on the appraisal team, then its accreditation requirements on new programs could be satisfied.

Therefore, it is recommended that:

(7:3) CODE undertake the appraisal of proposed new undergraduate programs, using essentially the same procedures employed by OCGS in regard to new graduate programs. Also, CODE should evaluate the need for each new program with respect to academic, cost and manpower considerations. In regard to such appraisal, CAB should participate so as to avoid unnecessary duplication and permit simultaneous accreditation.

2. *Periodic Accreditation of Existing Programs*

The universities maintain that the present accreditation system is not meaningful because it applies only to the setting up of a new program. Furthermore, programs in existence when accreditation was introduced in Ontario have not been accredited. Now, because of changes that have occurred, both in relation to curriculum and to the resources available for such programs, the profession should question the continuing validity of any accreditation. CAB is faced with the task of reassessing current curricula, since original accreditation is to expire in November of this year. It is to be undertaken only at the request or with the consent of both the provincial association and the educational institution concerned.

The question naturally arises: why should the universities respond to such requests? The answer is easy: if engineering, as a self-regulating profession, is responsible and accountable for man's physical environment, and if an engineering education is to prepare young people to enter the profession, then there should be an obligation on the part of educators to provide continuing assurance that their programs measure up to the needs of the profession. Moreover, in the past, accreditation has had a salutary effect on the enrolment patterns of several of the new engineering schools. Therefore, it is in the best interests of the universities to cooperate in matters related to accreditation, particularly as the students will want some assurance that the programs they enter will be recognized by the profession.

CPUO is beginning to develop data banks which could contain the quantitative information needed for re-accreditation. For engineering, the logical focus for this activity is CODE. It is in a position to coordinate the generation of data in response to its own needs, consistent with the form compiled by CPUO. As the stock of data expands, the task of re-accreditation should become easier, and in the long run the teams visiting a university will only be required to make qualitative assessments. The problem posed by data bank privacy may arise, but this is a matter that can be settled between CODE, CPUO and CAB. Therefore, it is recommended that:

(7:4) CAB re-accreditation, requested and/or approved by APEO, be coordinated through CODE, which ultimately should be in a position to provide the required quantitative data.

3. *Accreditation of Classes in Continuing Education*

We have recommended that classes in the part-time program of a university should relate

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directly to the syllabus of entrance examinations into the profession. This implies that the profession will have to address itself to the problem of accepting specific classes as credit towards registration. When such a plan is in operation, CAB and the provincial accreditation committees could be faced with a flood of detail on classes offered by each university. As an alternative, it would appear reasonable to follow the pattern proposed for new programs, and subject each one to a modified appraisal procedure. This could be facilitated by the use of data bank and computer techniques, which would appear to be the only tractable way of coping with such a large amount of detail. Information on classes in continuing education programs could be coordinated and provided to the accrediting bodies by CODE.

4. *Accreditation of Requalification Classes and Programs*

A similar argument applies for requalification classes. The accrediting bodies will face the problem; and again one solution would be the computer and data bank approach, with CODE coordinating the provision of necessary data to the accrediting bodies. A further element is the accreditation of classes and programs offered by the CAATs and the professional societies and associations; but this is a matter that lies beyond the scope of this study.

We have urged that there should be closer bonds between the educators and the profession. It was distressing to discover that only 59% of the teachers of engineering in Ontario are members of APEO (see page 30). If closer bonds are to develop, then this membership must approach 100% in order to be meaningful. We would recommend that:

(7:5) all engineers engaged in teaching in Ontario be registered members of the profession.

Education should be a continuing process. To expect that the effort put into the acquiring of a degree will carry a person throughout his life is to ask that time stand still from the day he graduates. And yet this is what happens in the lives of too many practising engineers. Because 60% of them move into managerial occupations (see page 49), it could be argued that continuing education in technical fields is not of first importance. But as managers, engineers are involved in decision-making — the basic ingredient of design — and so continuing education programs tailored for such engineers would take on special meaning in any requalification program. Ultimately, this could have a significant impact on the performance of Canadian industry.

This practice, if applied universally, would remove the permanency of the degree which is beginning to lose significance and meaning in a world of rapid change. Periodic requalification will make engineering careers more demanding, but the ultimate effect will be to improve the calibre of the professional engineer and enhance his stature in the technological society of today.

8

INDUSTRY

INTRODUCTION

At the beginning of Chapter 4, we suggested that there is a better than even chance that Jean will elect to enter the practice of his profession as soon as he receives his bachelor's degree. Whether or not he returns to pursue graduate studies at some time in the future, Jean probably will take a job in the industrial sector, in which 80% of all engineers in Canada work.[1] For this reason, we wish to examine the new environment facing Jean upon leaving university. This entails an analysis of the industrial attitude toward engineering graduates, and such considerations provide a background for speculation on future career patterns in engineering, and their implications with respect to the present engineering curricula.

THE INDUSTRIAL ENVIRONMENT

During his years as a student, Jean was judged on the basis of a value system that placed a high priority on academic ability. His survival in the educational milieu depended on his ability to prepare acceptable reports and to pass examinations and tests in order to demonstrate that he has mastered a certain body of knowledge. Now in industry, he will face a different value system, where he is expected to show qualities of motivation and leadership and where productivity is measured in terms of performance in achieving the goals and objectives identified with his role in the organization. This can be an unsettling experience for many young people, especially if they have not been exposed to such an environment gradually — through either summer employment or experience in a cooperative program.

Since Jean is a typical young engineering graduate, his first job will be technical in nature — research, design, development or operations.

[1]See Table 9-3.

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As he progresses in his career, he will discover that his education has prepared him not only for work of a technical nature but also for management where decision-making will be fundamental. But this is the essence of design — an iterative decision-making process. The technique of design develops characteristics that are common to the processes of management. If Jean displays qualities of leadership, a critical decision awaits him: whether to remain in technical work or to move into supervision and management. Usually, this occurs for most young engineers about seven years after graduation, by which time Jean will have taken on family responsibilities. He may be torn between a desire to pursue technical interests and so develop a technical reputation, or to move into management where there is more certainty of increased remuneration and greater security, together with the prestige associated with such an occupation. Most engineers choose the latter alternative.[2]

Also, during those seven years, technology will have moved so swiftly that if Jean failed to avail himself of opportunities for continuing education, obsolescence will have set in. Thus, the management alternative looks more attractive, particularly when younger engineers are moving into the profession and posing a serious threat to the position of the more senior practitioners and their aging technology. (The introduction of a program of requalification, as suggested in Chapter 7, could change this picture.)

What will Jean's decision be: to continue with his technical activity and gain an international reputation as a respected engineer, or to advance into the ranks of management or private entrepreneurship? We leave him at this point, for by this time Jean is well on the road to success, and with an education that should make it possible to find it on either road.

A part of this study involved interviewing sixteen corporate employers of engineers and technologists across Canada. This undertaking was a part of the manpower study to be described in Chapter 9, which gives an insight into the present industrial environment as it relates to the engineer. Most corporations tend to think of their engineers as potential managers, and several companies, principally in the primary industries, seek out engineers as their primary source of management material. It is now becoming common for companies to provide a parallel path so that an engineer can find an equal opportunity in either a technical or management occupation. Such a dual route, common in the high-technology industries, tends to avoid the dilemma faced by many engineers when they reach the crossroads described above. However, engineers who exhibit strong qualities of leadership and who are highly motivated invariably end up in management.

In engineering education, there is a traditional idea that engineers are "problem-solvers". For industry, it would be more correct to say that engineers "face situations". The role of an engineer requires him to face situations in which he takes account of psychological, sociological, aesthetic and political factors as well as scientific and technological matters. In weighing all of them together, he *formulates* problems that are soluble and tractable. Today, it is the computer and supporting staff that effect solutions to problems. Thus, the modern engineer requires more than traditional skills, and for success in the future he must have a basic knowledge and understanding of the applied humanities.

There is yet another traditional idea that relates to the industrial environment: that engineers there are "employees" who obey orders given by employers to whom they should tug their forelock each morning. According to this view, an employee engineer should not aspire to the high ideals of his profession, but instead, must do as he is told. However, the industrial picture is changing. In the past, power was passed downward as those at the top gave orders and those below either carried them out or relayed them further down the line. For the future, decisions in a business enterprise will be the product not of an individual but of a group of individuals. The complexities of modern technology, marketing, planning and organization have forced the creation of a mosaic of committees which embrace all those who bring specialized knowledge, talent and experience to group decision-making. Galbraith calls this organization the technostructure. He maintains that ". . . nearly all powers — initiation, character of development, rejection or acceptance — are exercised deep in the company. It is not the managers who decide. Effective power of decision is lodged deeply in the technical, planning and other specialized staff."[3] Today, engineers permeate the technostructure of any technologically-based industry in Canada and exercise a profound influence on corporate decision-making. Thus, professional responsibility in the context of Chapter 7 applies equally to the employee engineer and to those who are either managers or self-employed.

[2]See Figures 9-1 and 9-2.

[3]John Kenneth Galbraith, *The New Industrial State* (New York: Houghton Mifflin C., 1967), p. 69.

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The role of the engineer in industry is changing as he becomes far more productive than his predecessor. It is the computer that has made possible this expansion of his productive capacity, while supporting personnel have relieved him of many routine jobs, thus enabling him to work at a higher technical level. In interviews with engineering employers, it became evident that not all industries are learning how to use diploma technologists to the best advantage. In the sixteen firms surveyed, there were 43 technologists for every 100 engineers; whereas in the United States in 1968 the corresponding figure was 55.[4] In Canada these figures do vary from industry to industry; the engineer-technologist team is beginning to emerge as an efficient and productive unit. As more technologists become available and their values are recognized by an increasing number of industries, the productivity of the engineer and his advancement in the firm will be accelerated.

Companies with a heavy involvement in industrial research make little or no distinction between engineers and scientists. In such occupations the man's technical ability is of greater importance than his educational background. Most of these employers tend to pay little attention to professional registration. The proportion of engineers in Canada working in research is less than 6% (see Table 9-5).

Industry expects its engineers to be versatile. The educational experience up to the baccalaureate level has made some provision for this expectation, but graduate studies tend to create specialists whose versatility becomes overshadowed by strong personal interests and preferences. The increased professional competence acquired at the master's level usually outweighs any tendency toward specialization, but the situation can be quite different at the doctorate level. When a Ph.D. engineer enters a large firm he continues to work in a familiar environment, since research laboratories in such firms bear a striking similarity to those in universities. The new Ph.D. in a small firm usually experiences a severe shock when its more limited resources make it necessary for him to perform a much broader range of tasks. Often he must alter his priority of values in order to survive in this new milieu. For this reason, few doctorate engineers are to be found in small Canadian companies.

This qualitative description of some aspects of the engineer's industrial environment sets the stage for an examination of how industry views the engineering educational process.

[4]Engineering Manpower Commission of Engineers' Joint Council, *Demand for Engineers and Technicians — 1968.*

INDUSTRIAL ATTITUDES TOWARD ENGINEERING GRADUATES

In a practical sense, universities perform two necessary functions for industry — sorting and training. The sorting process determines who is to enter engineering school and who continue on to graduation, undertake graduate studies and receive advanced degrees. It involves both objective and subjective judgments on the part of faculty members. Most undergraduate education and virtually all graduate work is occupational training. The attitude of employers to university graduates has been aptly summarized by Kershaw and Mood as follows:[5]

> A prime attraction of the bachelor's degree to employers is the evidence it affords that the holder normally disciplines himself to carry out tasks somewhat conscientiously and on time no matter how irrelevant they may seem to be. That's why U.S. Steel does not mind hiring someone who majored in Finnish folklore.

Industry relies on the university to perform these functions, and accepts the possession of an engineering degree as evidence that such sorting and training has been accomplished. But engineering is a multi-portal profession, and an individual may enter it without possessing any degree. This egalitarian attitude is not universally accepted and many industrialists insist upon a degree as the proper ticket into management. Thus the non-degree engineer may find there is an upper limit to his advancement in the firm. As new avenues of post-secondary education develop, these barriers should disappear and companies will be forced to conduct the sorting function more thoroughly themselves.

Our survey of the sixteen Canadian companies disclosed — with the exception of research-oriented companies — an indifferent attitude towards a master's degree in engineering. Also there appeared to be a lessening of interest in engineers with a master's degree in business administration. In the words of one executive, "The M.B.A. expects to start too high, and is in too big a hurry to become vice-president." However, companies engaged in consulting and construction expressed a continuing high regard for the engineer-M.B.A., and most companies believe it to be of particular value if preceded by some years of industrial experience. Canada's economic environment has not been conducive to growth in industrial research, and this is reflected in the low hiring rates of Ph.D.'s

[5]Joseph A. Kershaw and Alex M. Mood, "Resource Allocation in Higher Education", *American Economic Review*, May 1970, p. 341. (Sorting and training were two of six major outputs of higher education suggested by the Public Policy Research Organization, University of California, Irvine.)

employed mainly to replace losses due to attrition. Canadian industry is not inclined to use Ph.D.'s in occupations outside the area of research and development.

Industry appears to be reasonably satisfied with the present generation of engineering graduates. The advent of major computer installations in the 1960s placed new stresses on engineering curricula. A need arose for increased emphasis on statistics, probability, numerical methods and computer programming. Today, the omnipresent computer contributes to an emphasis on analytical approaches to engineering problems at the expense of synthesis and experimental procedures. While the analytical approach is attractive because of savings in terms of time and money, many problems remain which lend themselves to experimentation.

At a conference in June of 1970,[6] engineering managers expressed the view that creative talent was being smothered by this overemphasis on analytical techniques. They feel that the majority of new engineers have too little background preparation in report writing, oral presentation of completed projects and selling new ideas to the organization, and inadequate understanding of other functions such as law, finance, accounting and personnel. One executive was of the opinion that engineering faculties tend to equate the attractiveness of career opportunities with the amount of research and development being conducted by a company. He believes that secondary industry needs engineers for operations as well as for research and development, and said: "Many graduates of engineering courses shy away from the marketplace and the factory. They appear to look inward as though hoping to find a solitary role conducting original research or preparing original designs, without interest for human service, marketability, cost or means of distribution. Others veer off into other pursuits such as teaching and government service."

There is still a gap in understanding between engineering educators and the practitioners of engineering. Most university teachers, with their orientation toward research and development, are well adjusted to the present curricula. Better compatibility between educator and industry demands better communication; a step in this direction was recommended in Chapter 6 (Recommendation 6:1).

Today's graduates are more sophisticated, more articulate and possibly more intellectually mature than were their predecessors.[7] As computers and supporting personnel are used more efficiently, increasing numbers of new graduates will be called upon to assume supervisory roles. This will create new problems for the graduate until he gains more practical experience, and in the process learns how to direct the efforts of people and so achieve a higher output from both technologists and technician. It would appear that employers in industry will expect to find these qualities in future engineering graduates, and this will present new and formidable challenges to the engineering educator.

OUTLOOK FOR FUTURE CAREER PATTERNS IN INDUSTRY

For the past decade, engineers and scientists in industry, government and the universities have been advocating and urging the growth of Canadian secondary industry. The federal government has woven a complex fabric of incentive programs directed toward such an expansion. These were devised principally for research and development, but now are being aimed at the entire innovative process, including marketing and tooling for production. It has been recognized that innovation is the key to export markets, and thus there is a strong justification for this approach in order to develop and expand the Canadian economy. Over a decade ago, when the new Ontario engineering schools were just starting up, engineering educators viewed one of their roles as giving support to this cause. They interpreted research and development as equivalent to innovation, and so believed secondary industry needed engineers with this kind of training. Although research and development are critical elements of innovation, all of the processes necessary to bring a new concept to market are involved — invention, design and production engineering, tooling, marketing and distribution. On the average, research and development amounts to about 5-10% of the total cost of innovation.[7a]

The hopes and aspirations of engineering educators for an expansion of industrial research and development failed to materialize. Although data are not readily available, in all probability the percentage of engineers entering industrial research and development is no greater than it was a decade ago. While volume of production by secondary industry may be increasing, profit margins are very low, particularly in the electronics and aerospace sectors where engineering is a major component, and in the chemical

[6] A symposium on "The Future of Engineering Education — Ontario", sponsored by the Ontario Engineering Advisory Council in Toronto, June 25 and 26, 1970.

[7] *Today's Engineering Graduates and Industry — Match or Mismatch?* Engineering Manpower Bulletin Number 16, June 1970.

[7a] Robert A. Charpie, *Technological Innovation: Its Environment and Management*, U.S. Department of Commerce, January 1967.

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industry, where "scale-up" factor is so important. The present business slowdown and changing patterns of governmental expenditure make the immediate future less certain than ever.

Canada appears to be going through a transition from an industrial to a post-industrial society — a society based on the culture of science and technology. The Harvard sociologist Daniel Bell has suggested that such a society has these five characteristics:

(1) the creation of a service economy with the majority of the labour force producing services rather than goods,
(2) pre-eminence of the professional and technical class,
(3) centrality of theoretical knowledge,
(4) commitment to growth and innovation,
(5) the creation of new technologies associated with retrieval, processing and storage of information, and systems engineering — what Peter Drucker calls the "knowledge industries".

In Canada, John Porter has written about the impact of post-industrialism. He suggests that "because knowledge is central to the post-industrial society, the dominant figures who are emerging are the scientists, the engineers, the mathematicians, the economists, all at home with the new computer technology. These stand in contrast to the dominant men of the industrial period, the entrepreneur, the businessman and the industrial executive."[8]

Much has been written and more has been said about foreign ownership of Canadian industry — the "branch plant" economy. Although there are some outstanding exceptions, most of these subsidiaries do little in the nature of research, development or design, but rather devote their efforts to manufacturing, sales and marketing operations. A further rationalization in the multi-national corporations could reduce the amount of manufacturing being carried on by them in Canada because of more favourable labour markets abroad. Over 60% of Canada's labour force is in some form of service activity,[9] and this will be the sector of greatest growth. Thus, Canada could be moving very rapidly into a post-industrial era where the knowledge industries will be dominant.

We have been told that Canada needs a thriving and growing secondary industry, exporting products abroad and employing an expanding labour force at home. However, we find that this type of industry has not grown as rapidly as expected and that the expanding labour force is being employed more and more in the service sector. It is as if the "industrial age" has passed us by. What then are the future career patterns for our engineers, and how should engineering schools be structured?

Some educators have said we must educate young people for the nation's needs of at least ten years ahead. They think Canada will require engineers in research and development, but now we are faced with a potential surplus of Ph.D.'s unless there is a slowing down of their flow into the economy.[10] The industrialists believe they know what they want in an engineer, and the numbers required; secondary industries, for the most part, however, are unable to plan more than a year or two in advance because of rapid fluctuations in markets and business cycles. Their predictions of future requirements have always been too low.

A central role for government is becoming clear. One of the characteristics of the post-industrial era is a continuing commitment to growth and innovation. This gives rise to a need for planning and forecasting, and adapting to technological change. Such planning is in its infancy, with the techniques of forecasting still relatively unsophisticated. The federal government is committed to the establishment of national goals, and these will determine future science, economic and social policies. Manpower requirements to meet these goals can provide a basis for educational policy. Such an approach may be theoretically sound but, no matter how well we define our plans, in practice there always must be a fair measure of "seat of the pants" decision-making. Nevertheless, a clear statement of national goals could be a valuable guide to educators.

In the present situation, it would appear best for engineering schools to follow a middle course. Until national goals are formulated and articulated, or until future trends become less obscure, young people should be educated so that they achieve a measure of versatility, and thus can move with equal ease into either the secondary or service sectors of industry. It is for this reason that we do not recommend any major alterations in the thrust of undergraduate studies. If there are sudden changes in govern-

[8]John Porter, "Post-Industrialism, Post-Nationalism and Post-Secondary Education", National Seminar on the Costs of Post-Secondary Education, The National Institute of Public Administration of Canada, Queen's University, May 1970.
[9]Economic Council of Canada, *Seventh Annual Review*, p. 15.

[10]Dr. Frank Kelly, Science Adviser for the Science Council of Canada, is reported to have said that while Canadian universities will be granting about 1,200 Ph.D.'s this year, only 500 to 600 will find employment — "and that is being very optimistic". Toronto *Globe and Mail*, November 18, 1970.

ment policy that generate requirements for new skills, they can be looked after by the graduate schools. New programs of the course-intensive master's variety can be developed quickly in response to change.

The outlook for future career patterns in industry is bright. In spite of uncertainties over the future direction of secondary industry, the engineer must play a central role in our post-industrial society. There are those who view its coming with apprehension because of imagined de-humanizing qualities. However, if its capacities are properly used, then its potential is enormous in the battle to improve the quality of life. The engineer must be prepared for his pivotal role and responsibility in a new age, and it is for this reason that we place great stress on the applied humanities.

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MANPOWER

We have traced the career pattern of a typical young engineering student from secondary school, through undergraduate and into graduate studies, and have made predictions about what he might find in each of these phases of his educational experience. We have examined the characteristics of members of faculty and the relationship between our engineering schools and the profession. Also, we have attempted to describe the industrial scene that will confront our young engineer when he leaves university. Before we proceed to a final survey of the overall system of engineering schools in Ontario, there is a need to understand the way engineers diffuse into the labour force in order to estimate the requirements for engineers from these schools. Once this information is available, then policies can be established for total enrolments at all degree levels, insofar as these matters are related to the utilization of engineers.

The first step is to look at the existing stocks of engineers in Canada — their field of employment and where they work, how their occupations shift with the passage of time after graduation, and future employment patterns within the profession. Next, one must attempt to estimate the number of engineers required from the Ontario schools at each degree level, in order to meet the anticipated demands of the economy and potential needs of the province and the nation. An enrolment projection of the supply of undergraduate engineering students for the decade 1970-80 can provide a basis for recommending policies covering the total engineering educational system in Ontario. Finally, a source review of engineering manpower statistics leads to a recommendation for a central data facility to meet a variety of regional and national needs.

CHARACTERISTICS OF ENGINEERING MANPOWER

Surprisingly little is known about our engineering manpower resources even though they are of growing importance to Canada. There is a dearth of data concerning the number of engineers, where they came from, and to what level or in what specialties they are educated. We cannot state with any certainty the fields in which they are employed, what functions they perform, how much they earn, or how they are distributed geographically across Canada or throughout industry. This kind of information is essential if there is to be effective educational planning. Such manpower statistics will make it possible for both industry and government to plan and to use the nation's human resources more efficiently.

A significant start has been made in developing detailed statistics. In 1967, the Department of Manpower and Immigration undertook a survey of scientists and engineers,[1] the first comprehensive effort to investigate this sector of the labour force (hereafter referred to as the 1967 Survey). It provided data in considerable detail on career profiles, including places of birth, educational attainments in various fields of study, types of employment and scientific experience. These profiles were cross-classified by fields of specialization, industries and regions of employment, salaries earned, and work functions. The survey population was estimated to be 77,000, of which 38,000 possessed engineering qualifications. Since the Canadian Council of Professional Engineers gives a figure for 1967 of approximately 60,000 as the number of persons residing in Canada who could be so categorized, the 1967 Survey represented about 63% of the total.

[1]A. G. Atkinson, K. J. Barnes and Ellen Richardson, *Canada's Highly Qualified Manpower Resources*, Research Branch, Programme Development Service, Department of Manpower and Immigration, 1970.

Employment and Field of Study

From the pool of scientists and engineers surveyed in 1967, it was possible to compare the field of employment with the field of study. These comparisons are shown in Tables 9-1 and 9-2. Approximately 80% of the engineering graduates claimed engineering to be their principal field of employment, whereas 91% of the group employed in this field were graduate engineers. A greater percentage of engineering graduates have remained with their profession than have graduates in the sciences, with the exception of architecture. Again with the exception of architecture, engineering employs more of its graduates than do the sciences.

These tables represent the total stock of engineers in 1967; they do not reveal recent flows into this pool. These flows could have altered substantially in recent years. Nevertheless, at each degree level, it is evident that traditionally this work has prepared young people for a career in engineering, since only one graduate in five (20%) has shifted at a later date into some other activity.

Sector of Employment

When estimating future patterns of growth and manpower requirements, it is important to know where engineers are employed, and this is shown in Table 9-3.

Table 9-1

DISTRIBUTION OF EDUCATIONAL BACKGROUND IN EACH FIELD OF EMPLOYMENT

FIELD OF EMPLOYMENT	FIELD OF STUDY: Architecture	Engineering	Physical Sciences	Life Sciences	Social Sciences	Other	Total*	No. in Sample
Architecture	94.4	1.4	0.1	1.2	0.1	0.8	100	2,198
Engineering	0.2	90.8	4.6	0.6	0.7	1.0	100	33,386
Physical Sciences	0.0	17.3	68.9	6.6	0.5	2.6	100	9,266
Life Sciences	0.1	10.0	2.9	82.2	0.4	1.6	100	7,780
Social Sciences	0.2	24.7	8.5	11.7	44.9	5.3	100	6,159
Other	1.7	23.7	28.7	18.8	4.7	17.0	100	6,051

*Total includes those who did not state their field of study.

Source: 1967 Survey of Scientists and Engineers, Department of Manpower and Immigration.

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Table 9-2

DISTRIBUTION OF EMPLOYMENT FOR EACH FIELD OF STUDY

FIELD OF STUDY	FIELD OF EMPLOYMENT Archi-tecture	Engineer-ing	Physical Sciences	Life Sciences	Social Sciences	Other	Total*	No. in Sample
Architecture	87.2	2.1	J.0	0.1	0.6	4.4	100	2,382
Engineering								
Total	0.1	80.4	4.2	2.1	4.1	3.8	100	37,842
Bachelor's†	0.1	79.7	3.9	2.4	4.4	3.8	100	32,417
Master's†	0.3	82.3	5.9	0.6	1.9	5.2	100	3,082
Ph.D.†	0.0	78.0	11.2	1.7	1.5	4.6	100	565
Physical Sciences	0.0	14.1	58.0	2.0	4.7	15.8	100	11,008
Life Sciences	0.3	1.6	6.3	65.7	7.5	11.7	100	9,747
Social Sciences	0.1	6.4	1.4	0.8	76.9	7.9	100	3,589
Other	0.8	15.1	10.4	5.7	14.1	44.8	100	2,289

*Total includes those who did not state their field of employment.
†Degree breakdown done especially for CPUO.
Source: 1967 Survey of Scientists and Engineers, Department of Manpower and Immigration.

Selected sectors for industry also are included in Table 9-3. The primary sector includes agriculture, forestry, fisheries, oil wells and mines — the resource industries. Under secondary would fall manufacturing and construction, which employ the largest number of engineers. Tertiary industry includes transportation, communications, utilities, trade and other service industries — the fastest-growing sector of our economy.

Table 9-3

DISTRIBUTION OF ENGINEERING EMPLOYMENT BY SECTOR

Sector	Percent	
1. *Industry*		
(a) Primary	7.0	
(b) Secondary	44.0	
(c) Tertiary	28.7	
		79.7
2. *Education*		
(a) University	2.4	
(b) Other	1.0	
		3.4
3. *Government*		
(a) Federal	5.2	
(b) Other	10.4	
		15.6
4. Not specified		1.3
TOTAL		100.0

Source: 1967 Survey of Scientists and Engineers, Department of Manpower and Immigration.

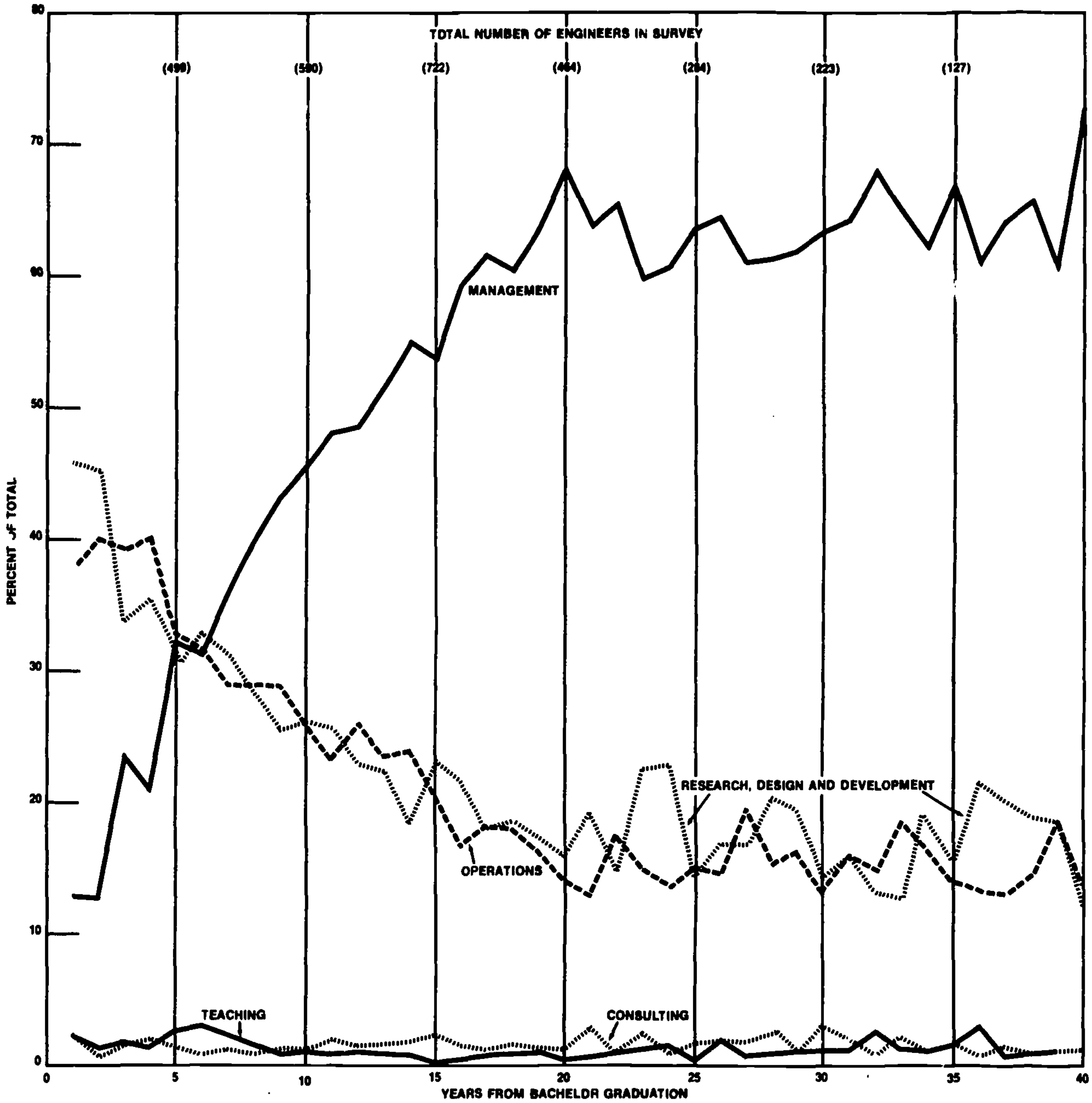
If education and government are combined with the tertiary industry sector to cover all service activity, the ratio of engineering employment in the resource, secondary and service sectors is approximately 1:4:5, compared with a 1967 total labour force mixture of 1:3:6.[2] This sectoral disparity between engineering and total labour force employment would suggest that a short-term adjustment could be taking place. The disparity would become less if recent graduates pursue careers more in the service sector than in the secondary sector. Such a trend could be accentuated by the depressed economic climate that is adversely affecting the expansion of secondary industry at the present time. The rapid growth of the service sector will alter future employment patterns of engineers.

Occupation

As a result of the 1967 Survey, it is possible to examine quantitatively, as a function of time, the occupational shifts of engineers from graduation until their retirement. This cross-sectional analysis measured the 1967 population in each occupational category as a function of years since graduation. The results are shown in Figures 9-1 and 9-2. Figure 9-1 refers to engineers with a bachelor's degree, while Figure 9-2 includes all engineers: those with bachelor's,

[2]Economic Council, *Seventh Annual Review*, Appendix Table A-2, p. 94.

Figure 9-1 — CROSS-SECTIONAL SURVEY OF ENGINEERING OCCUPATIONS FOR ENGINEERS WITH BACHELOR'S DEGREE
BASE YEAR — 1967



Source: 1967 Survey of Scientists and Engineers, Department of Manpower and Immigration.

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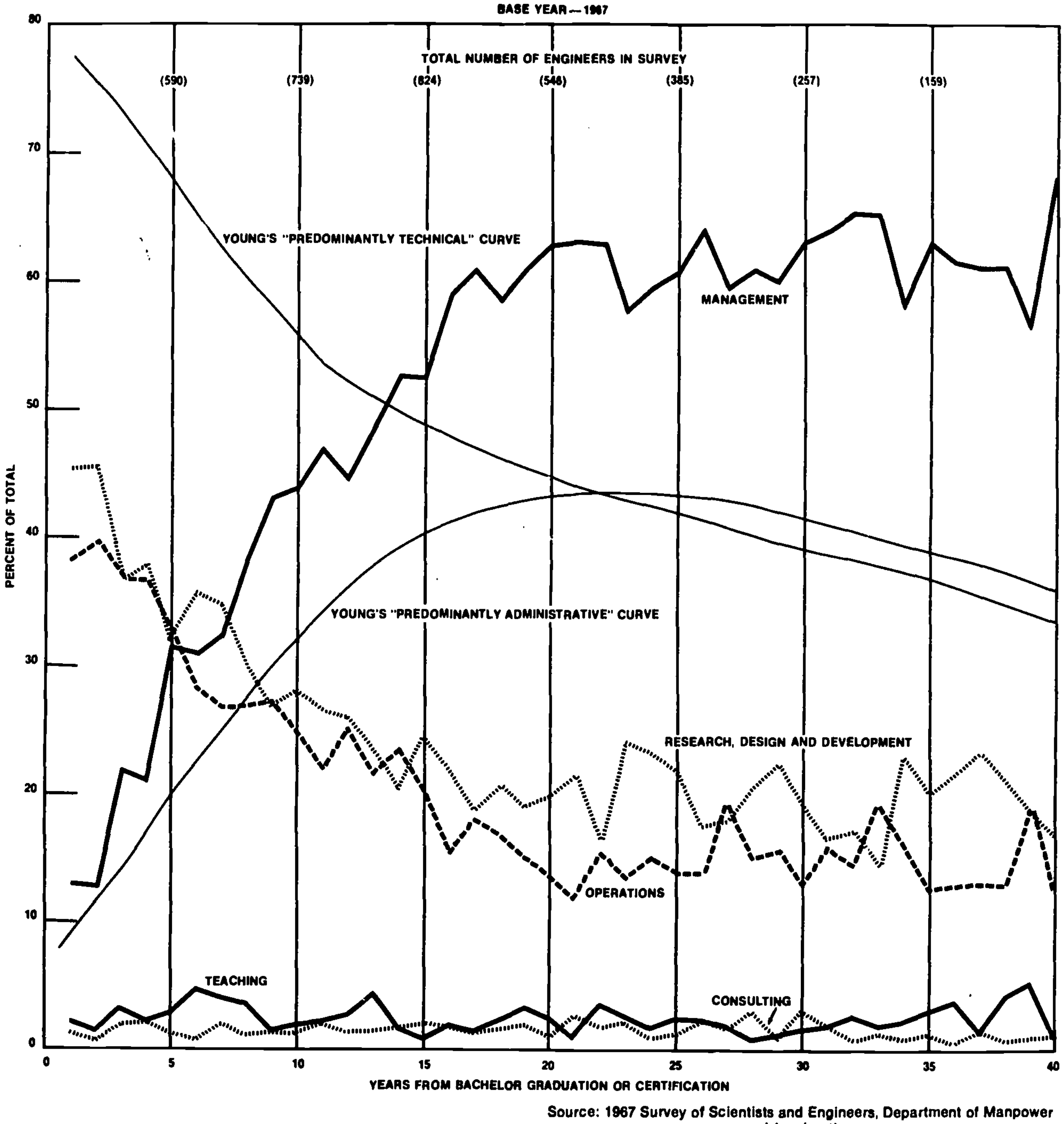
Figure 9-2 — CROSS-SECTIONAL SURVEY OF ENGINEERING OCCUPATIONS FOR ENGINEERS WITH PROFESSIONAL CERTIFICATION, BACHELOR'S, MASTER'S AND DOCTORAL DEGREES

BASE YEAR — 1967



Source: 1967 Survey of Scientists and Engineers, Department of Manpower and Immigration.

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master's, and Ph.D. degrees, and those registered without a recognized degree. The population of the last three was insufficient to draw separate curves. Twenty-one work functions were used to define occupations (grouped into five categories for the purpose of this study); these are summarized in Table 9-4.

Table 9-4

SUMMARY OF WORK FUNCTIONS USED IN CROSS-SECTIONAL ANALYSIS

Occupation	1967 Survey Work Function
Management	Administration, Management, Supervision.
Research	Management of Research and Development, Research.
Design and Development	Development, Production or Technical.
Operations	Construction, Installation, Erection, Field Exploration, Production, Operations, Maintenance, Testing, Inspection, Quality Control, Computer Service, Statistical Processing, Statistical Analysis and Forecasting, Personnel Training and Development, Extension Work in Agriculture, Publicity, Sales, Service, Marketing, Purchasing, Reports, Technical Writing, Editing.
Teaching	Teaching, Extension work.
Consulting	Clinical practice, Conselling, Practical case work, Industrial or Management consulting.

Figure 9-1 shows that over 80% of engineers holding a bachelor's degree were in technical work (research, design and development, or operations) in the year after graduation. This percentage falls off rapidly in the first fifteen years, then less rapidly until it reaches 32% at twenty-two years after graduation. Research, design and development maintained nearly identical percentages with operations throughout this period. The percentage of engineers employed in management increases rapidly to a maximum of 65% at thirty years after graduation, and then a decline sets in. Reasons for this drop could be shifts into consulting and teaching, retirements and withdrawals from the profession. The percentage of engineers engaged in consulting and teaching remains relatively constant at approximately 1½% each, until forty years following graduation.

Figure 9-2 includes the results of a survey of the 2,583 University of Toronto engineering alumni, conducted in 1944 by the late Dean C. R. Young.[3] Only technological and administrative categories are shown. The occupational mobility trends have not changed substantially over the twenty-three-year period, but now engineers move more rapidly into management.

The rapid flow of engineers into managerial occupations reveals the high value employers place on engineering education as a preparation for such work. Since the majority of engineers move into leadership roles, this underlines the need for communication and business skills. Engineers who remain in predominantly technical work are in either research, design and development, or in the operations field, in approximately equal numbers. The study group agrees with the point of view that maintains that such engineers require similar curricula. The basic knowledge and techniques used by the engineer in research, design and development are required by the operations engineer. Although work functions differ, the informational and organizational environments are similar.

Table 9-5 was developed from the 1967 Survey, using the occupations defined in Table 9-4. For each level of educational attainment, this table shows the occupational categories of highly qualified manpower who gave their field of principal employment as some branch of engineering. (About 91% of such people were engineers.) The percentage of those in research and teaching increases significantly with a rise in the level of education, while the percentage of those in management decreases. In design and development and in consulting, there are higher percentages of those with master's degrees than of those with other levels of education. For those with bachelor's degrees, the percentage in operations dominates other levels of education.

[3] C. R. Young, "Types of Employment among Engineering Graduates of Toronto", publication emanating from the Office of the Dean, Faculty of Applied Science and Engineering, University of Toronto, 1944.

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Table 9-5

HIGHLY QUALIFIED MANPOWER WITH ENGINEERING AS PRINCIPAL FIELD OF EMPLOYMENT - 1967
OCCUPATIONAL CATEGORY BY LEVEL OF EDUCATION

Occupational Category	Registered without Recognized Degree	Bachelor's Degree	Master's Degree	Doctoral Degree
Management	55.8	44.8	34.9	20.0
Research	3.4	4.3	12.0	35.7
Design and Development	15.0	17.3	22.6	7.8
Operations	17.9	23.0	13.1	2.1
Teaching	0.4	0.9	8.1	26.3
Consulting	1.6	2.5	4.4	2.5
Other, or Not Specified	5.9	7.2	4.9	5.6
Number in Sample (Approx. 91% Engineering Graduates)	1,665	27,830	3,194	643

Source: 1967 Survey of Scientists and Engineers, Department of Manpower and Immigration.

Table 9-5 sets out the primary associations of each level of educational attainment, from which an order of occupational priority has been tabulated (Table 9-6). This table has curricular implications and makes a good case for the course-work master's program, since it is at this level where management, design and development have a higher priority than research. Priorities for the other educational levels do not contain any surprises.

It is necessary to keep two points in mind when considering these data. First, the figures in Table 9-5 represent what existed in 1967, and not necessarily what is needed to shape our economy and society in the future. It may be that the priorities listed in Table 9-6 should be altered so as to mould the structure of the profession into a form different from what it is at the present time. However, before new priorities can be established with any confidence, reliable data of the type presented in Figures 9-1 and 9-2, and of the form developed in the 1967 Survey, are needed on a regular basis. Second, the existing data have been gathered at only one point in time. The composition of the manpower pool at any particular time should not be used as an indicator for flows into the pool. Reliable information on flows and their trends can be obtained only through regular sampling and detailed histories.

Table 9-6

OCCUPATIONAL PRIORITY WITH LEVEL OF EDUCATION

Level of Education	Priority	Occupation
Registered without recognized degree	1	Management
	2	Operations
	3	Design and Development
Bachelor's degree	1	Management
	2	Operations
	3	Design and Development
Master's degree	1	Management
	2	Design and Development
	3	Operations and Research
Doctoral degree	1	Research
	2	Teaching
	3	Management

Occupational mobility studies of the type just described are cross-sectional in nature: that is, they take a "snapshot" of the occupations of each person at one point in time, and create average career profiles, as set out in Figure 9-1. A more meaningful picture can be developed from a longitudinal, or cohort, study, in which a historical profile is traced for every individual, showing career transitions from graduation. Individuals are grouped, by year of graduation, into cohorts so that flow compositions into the manpower pool can be built on a historical base. In this way specific trends can be identified and future projections made with greater confidence. This is a tedious and costly process, but the results would be most useful in curriculum planning for degree programs, and would assist in determining the demand for continuing education. A study of this kind is being undertaken by the University of Toronto, whose 15,000 engineering alumni represent the largest such group in Canada.

In the above paragraphs and tables, we have described only those characteristics of engineering manpower that are needed in order to estimate gross requirements — employment by fields and sector, and occupational mobility. The 1967 Survey also provided data on student flows, the individual branches of engineering and other details including origin, sex distribution, geographical mobility and earnings. Unfortunately, in some of the statistics, scientists were combined with engineers — a difficulty experienced with much of the Canadian data assembled in the past.

REQUIREMENTS FOR ENGINEERS

It is necessary to distinguish between two separate concepts when assessing manpower requirements. One is need: the necessary mixture and flow of manpower required to meet objectives and goals; the other is demand: the aggregate of individual employment opportunities available within the economy. Ideally, need should equal demand, but needs cannot be readily identified because of their subjective nature and the complexities and structure of Canadian society. In countries with "planned" economies, attempts have been made to define needs on a national scale.[4] In both Canada and the United States some educators have even used need as the basis for justifying increased numbers of Ph.D. students. Whether correct or not, current employment opportunities for certain types of Ph.D.'s reveal a wide disparity between need and demand. At the micro-economic level, there is a growing awareness of the desirability of defining manpower needs, and many companies are beginning to specify their demands for manpower of all types in terms of need. In short, manpower planning is gaining equal status with capital and material resource planning.

It can be helpful to adopt the economist's approach to the problem: supply and demand must be equal, and the way in which they are equalized is by effecting adjustments to both sides of the equation. Supply is increased by attracting people from other fields by higher salaries and benefits, by retraining and upgrading employees, by working overtime, or delaying retirement. Demand is reduced by such means as re-defining jobs to require less skill, by shifting priorities of projects, and by automation. In effect, employers "make do" with existing personnel.

We have adopted the demand approach in projecting the future requirements for engineers. A separate study was undertaken to estimate the number of baccalaureate engineers required from the Ontario schools to meet demands over the period 1970-80. This study, embodied in a separate report[5] as a source document, is divided into two parts. The Substitution Study deals with the impact of the rapid expansion of diploma technologists and the possibility of employers substituting them for engineers. The Demand Study projects the demand for engineers over the present decade.

The Substitution Study

This study analyzed the results of interviews with sixteen organizations employing engineers. They included fourteen privately owned firms and two semi-autonomous government-related companies. They varied in size from three with under 750 employees to six with over 20,000. Head Offices were in three provinces, but all sixteen carry on operations in every province. Industries represented were pulp and paper, chemical, petroleum, steel, aerospace, electronics, electrical equipment, mining, motor vehicles, construction, transportation, utilities and consulting engineering. These sixteen organizations have over 250,000 employees including 7,500 engineers, 1,500 physical scientists, and 3,500 technologists and technicians. Only three firms had fewer than 200 engineers. It is estimated that one-tenth of all engineers in Canada were covered in this study.

It was discovered that technologists are not regarded as career substitutes for engineers, and that there are distinct barriers to the upward mobility of technologists. Substitution does take place in work functions, where there is a functional reorganization of the engineer's activity.

[4] Several communist countries have defined their manpower needs and planned accordingly with abysmal results; whereas Sweden, for example, has achieved moderate success in its national manpower planning.

[5] M. L. Skolnik and W. F. McMullen, *An Analysis of Projections of the Demand for Engineers in Canada and Ontario and an Inquiry into Substitution between Engineers and Technologists*, CPUO Report No. 70-2. (We are indebted to the Ontario Department of Education and the Canadian Department of Manpower and Immigration, who jointly supported this study.)

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When it becomes routine, often geared to a computer, this work is usually passed on to a technologist. The principal reasons for substitution appear to be changes in technology, rather than inefficiencies in manpower deployment or changes in relative wages and availability of technologists and engineers. Again, while engineers are required when a technology is first introduced, once it matures the engineers tend to be released in order to exploit new fields, while technologists move in to replace them.

The relative supplies of engineers and technologists appeared to have little influence on manpower demands, but the absolute supplies of both engineers and technologists were of importance. When the number of engineers decreased substantially (e.g. mining, metallurgy and geology), technologists were substituted to meet the demand. The number of available technologists influences the speed of adjustment to changes in technology. A more rapid response was possible when trained technologists were readily available as an alternative to in-plant training.

The conclusion of the study is that the increasing numbers of diploma technologists now graduating from the Colleges of Applied Arts and Technology will not have a significant effect on the demand for engineers. Indeed, the availability of technologists should permit engineers to use their skills more efficiently.

The Demand Study

This study focused on three major independent attempts to forecast the future demand for engineers.[6] All of these studies relied upon census data, the most recent being for the year 1961. They were compared by applying the basic method of each to the twenty-year period 1961-81, in order to arrive at a projected growth for the stock of engineers. Then, the growth rates so derived were compared with the growth rate of the gross national product (GNP).

Between the last two census years, 1951 and 1961, the stock of engineers in Canada grew at a rate of 3.5% a year compared to a yearly increase in GNP of 3.6%, or even higher if one adjusts for the cyclical differences between the two census years. For the period 1961-81, GNP is expected to grow at an average rate of no more than 4% a year. Two of the projections were below this percentage, while the other was substantially higher. Each projection used different attrition rates in attempting to develop the required in-flow of engineers.

In a fourth projection, it was assumed that the stock of engineers would expand at the same rate as the GNP (4.0% a year), while attrition continues at the highest rate used in the three studies (Ahamad's). This produced a required average annual in-flow of 3,400 engineers for the Canadian economy over the period 1961-81. Adjusting for net immigration and the number of degrees awarded in Canada from 1961 to 1968, the final projection for the thirteen-year period 1968-81 was 3,300 engineers a year.

Historically, about 35% of Canadian engineering degrees have been awarded in Ontario, whereas nearly 50% of them are employed in that province. To remain on the safe side, it has been assumed that 35-50% of the national inflow will come from Ontario. The percentage must take into account net immigration, and those graduates who do not enter engineering employment after graduation. There is a tendency to overestimate net immigration figures because the data cover immigrants who record "engineering" as their hoped-for occupation, and emigration figures normally are quoted only for the United States. (Although about 20% of baccalaureate engineers currently proceed to graduate studies in Ontario, ultimately they do enter the labour force mainly in engineering.) Insufficient data are available on the number of engineering graduates who take up engineering occupations after graduation, but it is known that increasing numbers return to study medicine, law and business administration. There is no reason to believe that such factors offset one another. Skolnik concluded that the demand for Ontario engineering graduates will be about 1,500 graduates a year during the period 1968-81, and suggests an upper limit of 2,500 a year, derived from the Ahamad study.

This forecast extrapolated from past trends. Thus, it did not take into account major structural changes in society that create discontinuity between present and future. For example, the Substitution Study concluded that the mix of technologists and engineers depended mainly on technological change rather than on relative supplies of people and the wages paid to them. For this reason, it was felt that the demand forecast for engineers should not be affected by the rapid increase in the number of diploma technologists entering the labour force. However, in the present era of technological change, it is hazardous to show a smooth projection of past

[6]N. Ahamad, *A Projection of Manpower Requirements by Occupation in 1975, Canada and its Regions* (Ottawa: Department of Manpower and Immigration, 1970); N. Meltz and G. P. Penz, *Canada's Manpower Requirements in 1970* (Ottawa: Department of Manpower and Immigration, 1968); C. Watson and J. Butorac, *Qualified Manpower in Ontario 1961-86, Vol. I: Determination and Projection of Basic Stocks.* (Toronto: Ontario Institute for Studies in Education, 1968).

trends in variables greatly influenced by technology. The Canadian economy has been reasonably flexible and to date has managed to adjust to wide variations in the number of graduates in any particular field.

In the above forecasts, no attempt was made to divide engineering into its different branches. Over a long span of time, shifts in demand from branch to branch can be extreme. For example, up to 1961, civil engineering had the largest population, and engineering projections based on the census data continued to show the dominance of civil engineers. But the 1960s were highlighted by an explosive expansion of electronics, and the 1967 Survey reveals electrical engineering as occupying 19% of the total, compared to only 16% for civil engineering. A more detailed study of recent flows into employment by branch is required in order to produce meaningful predictions, and even then technological change and public preferences may continue to upset predictions.

Appendix G summarizes the recent experience of the universities in placing engineering graduates. The demand for bachelor graduates continues to be brisk even though very recent trends reflect the present slump in the economy. We expect this condition will be of short duration, and have assumed a recovery in growth early in the 1970s.

A reasonable substitute for recent flows into employment is the output of bachelor's degrees, divided into the different disciplines (shown in Appendix B). These flows do not account for current fluctuations in demand (such as the present shortage of mining, metallurgical and geological engineers), but they do give an indication of broad trends over a five- to ten-year period. It will be difficult to predict demand by branch with any degree of certainty until a regular survey is conducted on an annual basis. Shortages in some branches can be filled by graduates from another branch. This type of horizontal substitution occurs when a graduate in civil engineering is employed as a mining engineer, but a vertical substitution also takes place where vacancies in mining engineering are filled by mining technologists. In these ways, the economy adjusts itself to equalize supply and demand.

Bachelor's and Master's Graduates

The demand for individuals holding advanced degrees has not been estimated quantitatively for this study. Surveys conducted in the United States[7] reveal that, except for those companies engaged in research and development, employers do not encourage their engineers to pursue advanced degrees. The impetus behind the burgeoning growth of graduate schools has been the aspirations of faculty to develop departments, and of students for higher levels of learning and professional competence.

Table 9-6 shows that in Canada there are similar employment patterns for bachelor's and master's degree engineers, but marked differences between them and the holders of doctoral degrees. Therefore, we have grouped together the demand for master's and bachelor's degrees, and have treated separately those with doctoral degrees.

As suggested in Chapter 4 (page 14), a master's degree will develop increasing significance as the service industries become a focal area of growth and sophistication. With Canada's move into the post-industrial era, there should be an increasing flow of engineers into the service sector, and this implies a demand for specialty skills to satisfy the wide variety of tasks executed by these "knowledge" industries.

In the future, more Canadian employers will be forced to insist on a master's degree for certain specialized skills. Table 9-5 shows that 23% of the master's degree engineers were employed in design and development in 1967. The contribution of the specialist master's degree engineer to intensive innovation in Canada's secondary industry, where design and development constitute the major allocation of resources, cannot be ignored in any assessment of demand. Nevertheless, to date there has been no clear articulation on the part of employers in these industries.

Since a quantitative measure of demand is not possible, we have been forced to make the above qualitative and subjective judgments of need. The demand for master's degree engineers is included in the annual figure of 1,500 engineering graduates, but on the basis of the anticipated needs of our economy, universities should be responsive to those who wish to pursue work to the level of a master's degree.

Doctoral Graduates

In estimating demand for the doctorate in engineering, one must bear in mind both the high cost of such programs and the recent concern of many such graduates over the lack of employment opportunities. Table 9-5 shows that

[7]*Goals of Engineering Education*, ASEE Final Report, 1968, p. 35 and Figure D-16.

engineers with doctoral degrees move principally into teaching and research careers, and Appendix G reveals trends in the placement of Ph.D.'s.

The demand for teachers was estimated on the assumption that the universities will maintain present student/staff ratios while drawing additional faculty almost exclusively from the pool of Ontario Ph.D.'s. While both assumptions are assailable, the result will give a maximum number. The calculation used a student/staff ratio of 13:1, which was the average for Ontario universities over the past ten years, and it was based on an annual attrition rate of 3.4%. The figure is close to 10% for the individual university, but only 3.4% are lost from the provincial system as a whole. Undergraduate enrolment projections, covered later in this chapter, estimate a growth from 8,500 undergraduates in 1969-70 to 13,000 in 1980-81. Using these figures, the average demand for additional faculty will be about 62 a year throughout the decade. This figure is an upper limit because of the recommendation in Chapter 6 that, where possible, vacancies should be filled by members of the practising profession, not all of whom will possess a doctoral degree. On the other hand, it is to be hoped that teaching posts in both the Colleges of Applied Arts and Technology and in the high schools will attract more engineers. Therefore the demand for teachers educated as engineers in Ontario universities was assumed to be 60 Ph.D.'s a year over the next decade.

No attempt was made to assess the demand for post-doctoral fellows. Usually such appointments are for one or two years, and thus are a kind of holding operation before the individual takes on permanent employment. The load on demand, averaged over a ten-year period, would be negligible.

The demand for research is more difficult to determine because of the present state of the Canadian economy. In industry, the growth rate for total expenditures on intramural research and development has decreased significantly since 1964. DBS figures[8] reveal the following growth rates: 1964, 26%; 1965, 27%; 1966, 10%; 1967, 7% and 1968, 3%. These figures, adjusted for a 6% "inflation-sophistication" factor[9] show a sharp decline in industrial research and development activity. Prospects for a reversal of this trend in the near future do not appear at this time. The present austerity program of the Canadian government, coupled with its desire to shift more research into the industrial sector, means that opportunities of employment at the federal level for engineering doctorates are equally low. Over the present decade research activities probably will remain relatively static, and therefore the demand for research engineers will consist almost entirely of the need for replenishment to make up for yearly attrition. The existing stock of engineers engaged in such activities in industry and in government is approximately 2,000 (1,000 in each sector) and consists of 3% with professional certification, 64% with bachelor's degrees, 21% with master's degrees and 12% with doctoral degrees.[10] In spite of this present mix, we have assumed that existing stocks will be replaced with a much higher proportion of Ph.D.'s and that this replacement will consist of 60% doctoral graduates. By 1980 a 5% attrition would create a demand for approximately 60 Ph.D.'s a year for Canada, and we have assumed that about one-half of this number will be drawn from Ontario.

A small proportion of doctorate engineers move into occupations other than teaching and research (Table 9-5). In recent years, such occupations probably have been associated with the service sector, but figures are not available to substantiate this statement. We have assumed that 10% of the total demand for engineers with a doctorate will result from employment opportunities outside teaching and research. Table 9-5 shows that 20% of them are in management. Since they normally do not move into these positions immediately upon graduation, we have combined any demand for this occupation in the 10% figure suggested above.

From the foregoing, it appears that the Canadian demand for engineering doctorates from the Ontario universities over the present decade will be about 100 a year. This figure appears reasonable in the light of current economic circumstances, but it must be reviewed regularly — at least every five years — because of rapid changes in technology and public opinion that will offset the economic and political climate over the balance of this century.

A survey has been made of the anticipated country of employment for the Ontario engineering graduate students enrolled in 1968-69.[11] About 55% planned to work in Canada, 15% in a foreign country, and 30% had no idea. A survey[12] of the present employment of the holders

[8] *DBS Daily*, 25 April 1969.

[9] For a full discussion and derivation of this factor, see R. W. Jackson, D. W. Henderson and B. Leung, Background Studies in Science Policy: Projections of R and D Manpower and Expenditure, Special Study No. 6, Science Council of Canada, 1969, Section 2.

[10] 1967 Survey of Scientists and Engineers.

[11] Summary produced by the Program Planning and Analysis Group — Manpower Section, National Research Council, July 1970.

[12] Survey conducted by the Ontario Council on Graduate Studies in 1969.

of the 231 Ontario doctorates in engineering awarded between 1964 and 1969 reveals that of the 197 Ph.D.'s whose locations are known, 54% were employed in Ontario, 28% in the rest of Canada, 14% in their home country and 4% in some other country. It is unlikely that emigration to the United States will continue at recent levels because of the present scarcity of employment opportunities for engineers there. However, the U.S. Engineering Manpower Commission estimates that by 1972[13] demand will again overtake supply. It would appear that about 20% of the Ontario Ph.D. graduates will leave Canada for employment elsewhere, and allowing for such emigration, the total output of Ph.D.'s ought to be 125 a year.

In summary, the anticipated demand for engineers from Ontario universities, averaged over the decade 1970-80, is as follows:

Bachelor's degree	—1,500-2,500 a year
Master's degree	—Included in the figures for bachelor's degree; the number will depend on the intentions of students.
Ph.D. degree	—125 a year.

SUPPLY OF UNDERGRADUATE STUDENTS

The term "supply" is used here to designate the supply of engineers into the economy from the Ontario engineering schools, which depends to a large extent upon the student population stream into the freshman year. Enrolment projections are of such importance to this study that they were treated in some depth and embodied in a separate report as a source document.[14] Since 87% of Ontario undergraduates are from that province[15] it appeared reasonable to use Ontario statistics and high school data. An analysis of the entrance requirements for its engineering schools shows that, for 1969-70, grade 13 students must have successfully completed mathematics A and B, physics and chemistry. Other required subjects vary, but a minimum standing (usually 60%) is necessary in some or all of them, together with an adequate over-all standing in grade 13.

Since 1955, there has been a declining interest in both physics and chemistry (Fig. 9-3). Even though high school enrolments continue to climb and a greater proportion of high school graduates attend university throughout the 1970s, a declining interest in physics and chemistry will offset these upward trends. Total engineering enrolments should level off near the 1970 figure, in a band between 8,000 and 8,300 students. This would occur if the Ontario high school curriculum and engineering entrance requirements continue in their present form. However, Ontario high schools are changing, and it is expected that some form of a credit system will be introduced whereby students can proceed at their own pace toward graduation. Under such circumstances, universities will be forced to redefine their entrance requirements as recommended in Chapter 2 (Recommendation 2:1), and these could vary between different regions of the province.

A constant total enrolment of 8,000-8,300 students would result in a steady-state bachelor degree output of approximately 1,400 a year or 100 below the minimum set by demand. The final enrolment projection was undertaken on the assumption that neither physics nor chemistry would be mandatory for engineering, as it is at the present time for most schools, but that grade point averages would be maintained at the same academic level. In this way, engineering and science faculties would draw from the same pool of high school graduates. Using this projection (Fig. 9-4), freshman enrolments would build up to 4,000 students and total enrolments to a level of 13,000 students by the year 1980-81. (Figure 9-4 includes the universities' projections for total enrolments. The lower branches of the curves are the estimates when entrance requirements for engineering remain unchanged.) This final projection yields an average of about 1,750 bachelor's degrees a year over the period 1968-81, and falls within the range of demand summarized above.

SUPPLY OF GRADUATE STUDENTS

The pool of these students in Ontario is made up of Canadians who move directly into graduate studies after their baccalaureate degree, students who have one or more years of practical experience and students who are landed immigrants or foreign nationals. Unfortunately, it was not possible to obtain a complete cross-section of this mixture, but Table 9-7 does show the citizenship of Ontario engineering graduate students for the years 1968-69 and 1969-70. In the latter year, approximately one-half were Canadians, one-quarter landed immigrants and one-quarter foreign nationals. In the previous year the foreign student component had been one-third, and the difference was taken up by

[13] *Engineering Manpower Bulletin*, Number 17, September 1970.
[14] Philip A. Lapp, *Undergraduate Engineering Enrolment Projections for Ontario, 1970-1980*, CPUO Report No. 70-1.
[15] Z. E. Zsigmond and C. J. Wenaas, *Enrolment in Educational Institutions by Province, 1951-52 to 1980-81*, Staff Study No. 25, Economic Council of Canada, January 1970.

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increased numbers of landed immigrants. (Probably this was caused by a change in the National Research Council policy: graduate fellowships are now being awarded only to Canadian citizens and landed immigrants.)

Table 9-8 shows the age and sex of Ontario engineering graduate students for the academic year 1968-69, and since 72% were 26 years of age or older, usually they have had one or more years of practical experience before embarking on graduate studies. It would appear that the majority of those entering engineering make their initial plans only as far as the bachelor's degree. After obtaining employment and learning more about the profession, with its opportunities and challenges for those with more education, they raise their sights to the master's or doctoral degree level. Table 9-7 reveals that 22% in 1968-69, and 24% in 1969-70, were part-time students who, for the most part, pursued an advanced degree while working in industry or government.

It is possible to make a rough estimate of the mix in the supply of graduate students: of the total stock in 1969-70, approximately 30% moved directly into graduate studies while 70% had had some professional experience. About one-third of the latter group were employed as engineers while pursuing graduate studies on a part-time basis. One-quarter of the graduate students were foreign nationals, and less than 6% of these were part-time students (from Table 9-7). The percentage of foreign nationals with experience prior to graduate study is not known.

Table 9-7
CITIZENSHIP OF ONTARIO ENGINEERING GRADUATE STUDENTS
1969 and 1970

	CANADIAN		LANDED IMMIGRANT		FOREIGN														TOTAL	
					U.S.A.		U.K.		EUROPE		ASIA		AFRICA		OTHER		SUB-TOTAL			
Year Ending	69	70	69	70	69	70	69	70	69	70	69	70	69	70	69	70	69	70	69	70
Doctoral	236	230	101	169	9	8	3	6	10	13	122	88	15	19	17	7	176	141	513	540
Full-Time %	46.0	42.6	19.7	31.3	1.8	1.5	0.6	1.1	1.9	2.4	23.8	16.3	2.9	3.5	3.3	1.3	34.3	26.1	100	100
Doctoral	59	72	13	21	1	1	1	—	1	—	6	3	—	1	—	1	9	6	81	99
Part-Time %	72.8	72.7	16.0	21.2	1.2	1.0	1.2	—	1.2	—	7.4	3.0	—	1.0	—	1.0	11.0	6.0	100	100
Master's	405	372	191	218	8	4	27	20	30	27	255	206	39	35	39	35	397	327	993	917
Full-Time %	40.8	40.6	19.2	23.8	0.8	0.4	2.7	2.2	3.0	2.9	25.7	22.5	3.8	3.8	3.9	3.8	39.9	35.7	100	100
Master's	247	252	60	97	1	2	5	1	1	—	34	18	—	—	5	1	46	22	353	371
Part-Time %	70.0	67.9	17.0	26.1	0.3	0.5	1.4	0.3	0.3	—	9.6	4.9	—	—	1.4	0.3	13.0	6.0	100	100
Total	947	926	365	505	19	15	36	27	42	40	417	315	53	55	61	44	628	496	1,940	1,927
Total %	48.8	48.1	18.8	26.2	1.0	0.8	1.9	1.4	2.2	2.1	21.5	16.3	2.7	2.9	3.1	2.3	32.4	25.7	100	100

Source: CPUO Research Division.

Table 9-8
AGE AND SEX OF STUDENTS ENROLLED
FOR THE MASTER'S AND DOCTORATE
IN ENGINEERING AT ONTARIO UNIVERSITIES
1968-69

AGE GROUP	ENROLLED FOR MASTER'S			ENROLLED FOR DOCTORATE			TOTAL ENROLMENT			
	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	(%)
Under 23	38	0	38	4	0	4	42	0	42	(2)
23 — 25	408	9	417	86	0	86	494	9	503	(26)
26 — 28	382	5	387	212	0	212	594	5	599	(32)
29 — 31	194	2	196	159	0	159	353	2	355	(19)
Over 31	240	1	241	152	1	153	392	2	394	(21)
TOTAL	1,262	17	1,279	613	1	614	1,875	18	1,893	(100)

Source: Programme Planning and Analysis Group — Manpower Section, National Research Council of Canada, July 1970.
NOTE: Totals in this table differ slightly from those in Table 9-7, owing to differences in definition of some graduate programs by NRC and CPUO.

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Figure 9-3 — PHYSICS AND CHEMISTRY — GRADE 13 DEPARTMENTAL EXAMINATIONS
PERCENTAGE OF GRADE 13 STUDENTS ACHIEVING PASS — 50% OR BETTER

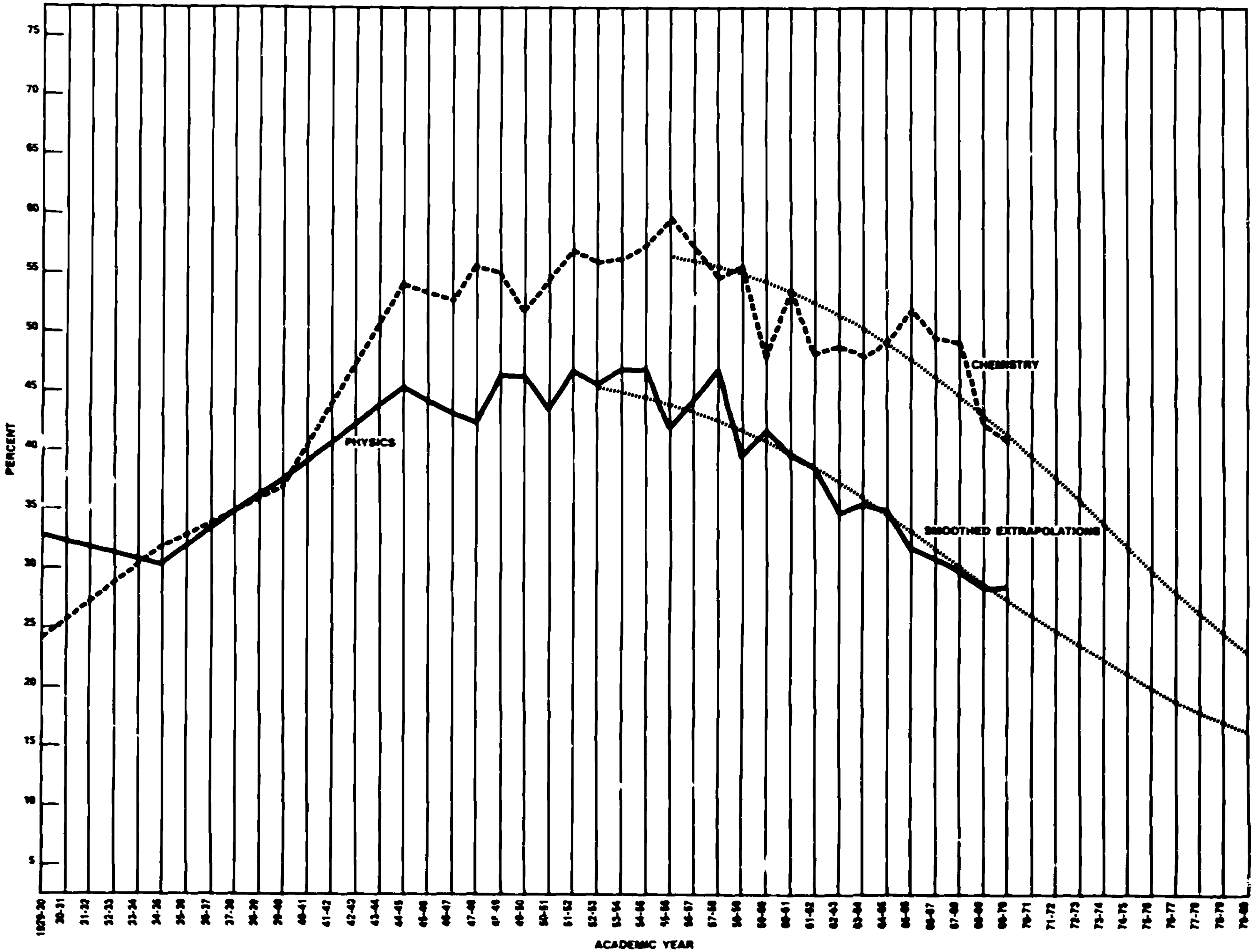

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Figure 9-4 — ENGINEERING UNDERGRADUATE ENROLMENTS

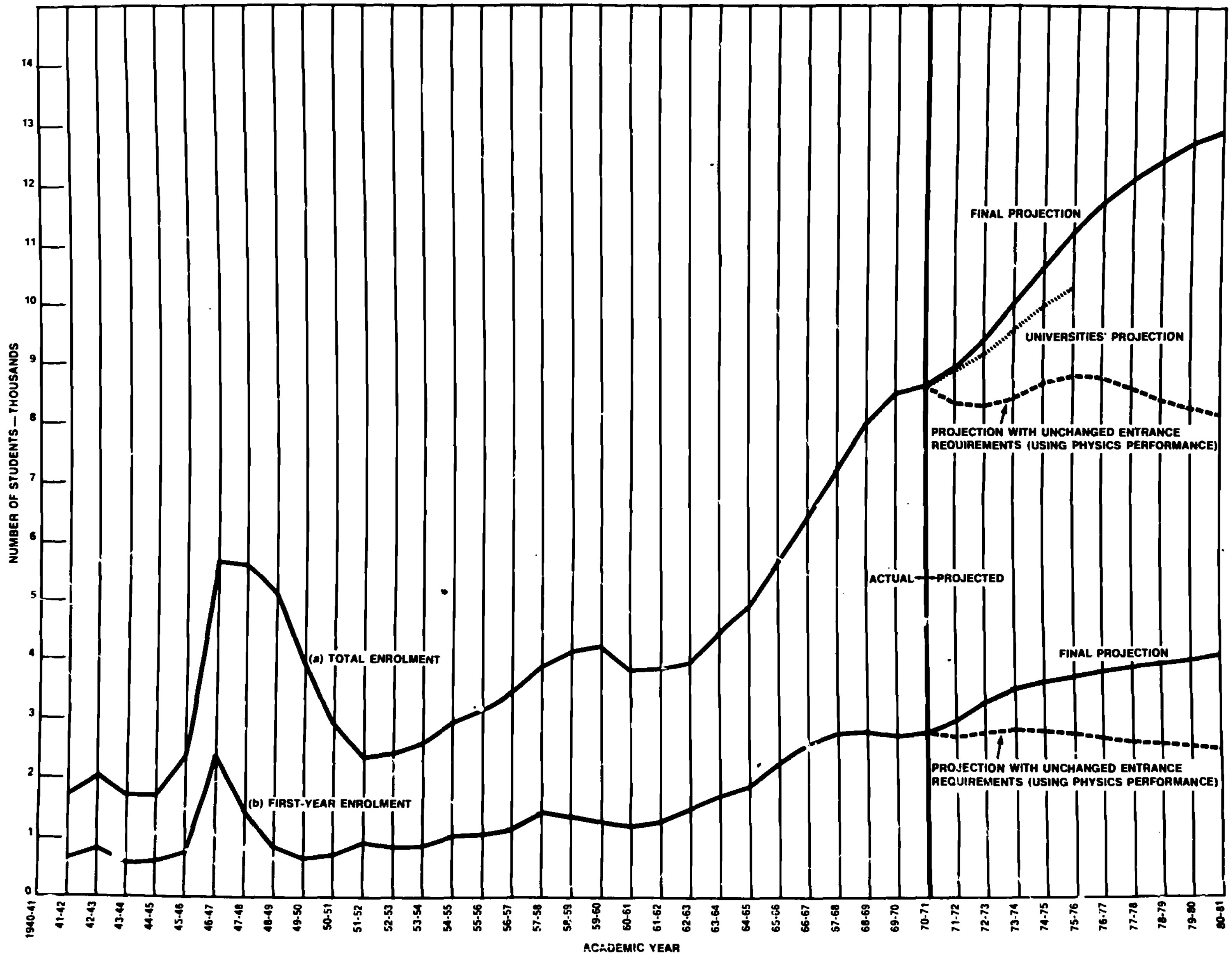
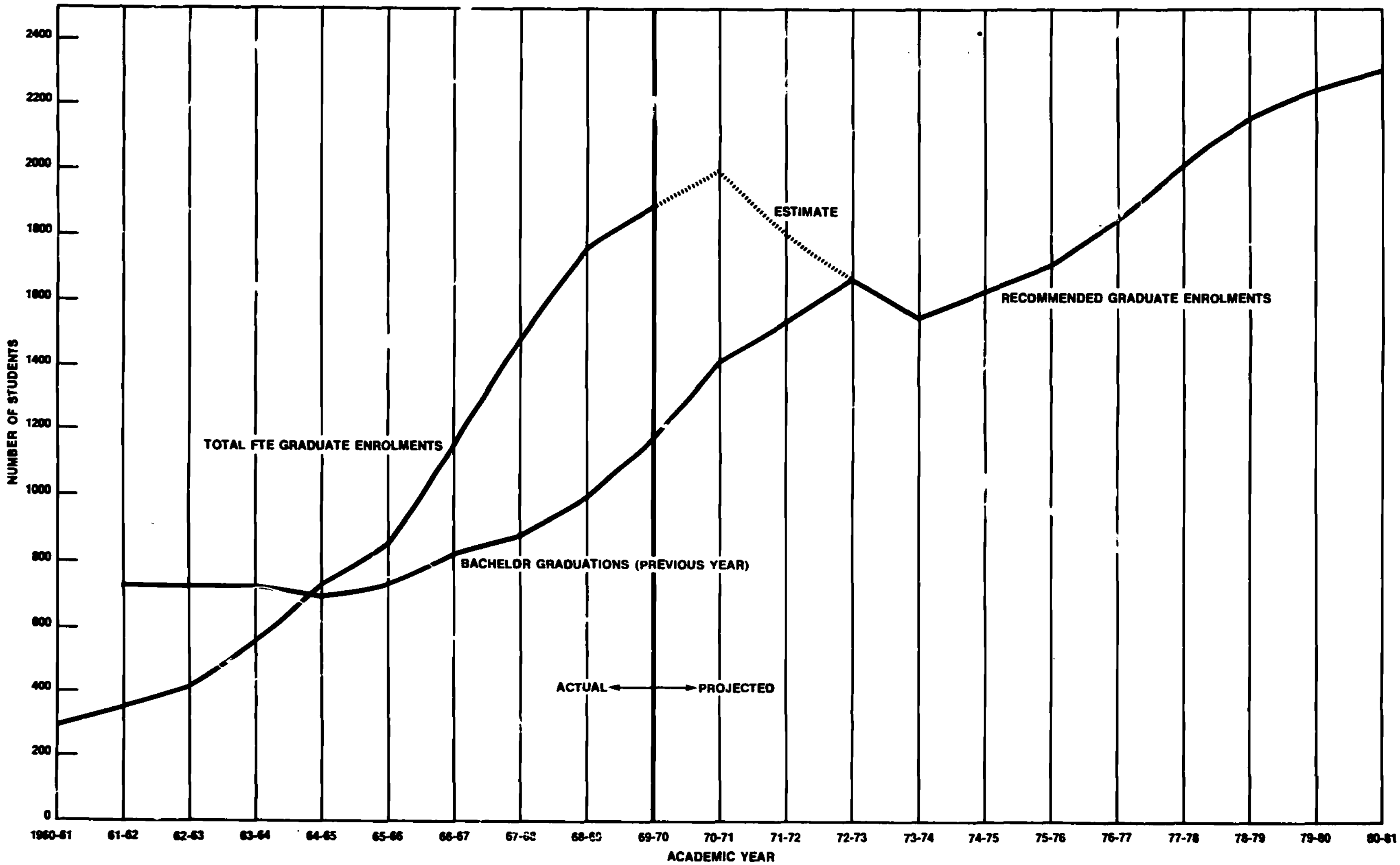


Figure 9-5 — ENGINEERING GRADUATE ENROLMENTS —ONTARIO



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Student intentions should play a major role in determining the supply of graduate students. A rough measure of such intentions can be developed from an analysis of student flows into graduate studies. Table 9-7 reveals that, in recent years, 48% of the Ontario engineering graduate students have been Canadian citizens. Table 9-9 shows that, in any year, the ratio of this Canadian component to bachelor graduations from Ontario of the previous year rose during the early 1960s, levelling off in 1967, to remain relatively constant at approximately 80%. This last figure represents the intentions of Canadian students, at the present time, to pursue graduate studies in the Ontario engineering schools and is based on bachelor graduations — the principal "feed" mechanism for these schools.

Table 9-9

CANADIAN GRADUATE ENROLMENT FROM BACHELOR GRADUATIONS FOR THE ONTARIO ENGINEERING SCHOOLS

Academic year	F.T.E. Graduate Enrolment — Ontario	(A) Canadian Graduate Enrolment — Ontario*	(B) Ontario Bachelor's Degrees Awarded Previous Year	A/B Percent
1961-62	348	167	705	23.7
1962-63	416	200	707	28.3
1963-64	558	268	705	38.0
1964-65	728	349	682	51.2
1965-66	851	408	708	57.6
1966-67	1,158	556	810	68.6
1967-68	1,482	711	869	81.8
1968-69	1,764	847	991	85.5
1969-70	1,893	909	1,142	79.6

*Assumed to be equal to 48% of total F.T.E. graduate enrolment, a figure that has only been confirmed for 1968-69 and 1969-70.

Over the past decade there has been a rapid growth in enrolment at the graduate level and this has meant an upward surge in expenditures. The cost study, summarized in Appendix H, has revealed that, in many instances, the diversion of faculty time from undergraduate to graduate students became excessive, particularly when there was a high ratio of graduate to undergraduate students. For these and other reasons brought out in this report, it is felt that the "numbers game" in graduate studies should be curbed, and for the future graduate enrolments should be related more directly to the growth of undergraduate enrolments.

At the present time, the intentions of Canadian engineering students to pursue graduate studies in Ontario can be accommodated while limiting such enrolments to about 80% of those receiving bachelor's degrees. A 10% minimum foreign student enrolment has been recommended for the province's graduate schools.[16] The study group agrees with this recommendation, and is allowing an additional 10% to permit some growth in the participation rate and for landed immigrants. Therefore, graduate student enrolments should be maintained at a level equal to the number of those receiving bachelor's degrees in the previous academic year.

Figure 9-5 and Table 9-10 summarize the recommended graduate enrolments for the period 1968-80, together with the forecast of bachelor's degrees derived from undergraduate enrolment projections.[17] We recommend that:

(9:1) over the next two years the estimated graduate enrolment of 2,000 for 1970-71 be reduced by 17%, after which graduate enrolment should be equated to the previous year's bachelor graduations.

Table 9-10

RECOMMENDED ENGINEERING GRADUATE ENROLMENTS, PROVINCIALLY-ASSISTED UNIVERSITIES, ONTARIO, 1968-1980

Academic Year	Engineering Bachelor's Degrees (previous year)	Recommended Graduate F.T.E. Enrolment
1968-69	991	1,764
1969-70	1,170	1,893
1970-71	1,416	2,000 (estimate)
1971-72	1,540	1,800
1972-73	1,664	1,664
1973-74	1,558	1,558
1974-75	1,639	1,639
1975-76	1,717	1,717
1976-77	1,848	1,848
1977-78	2,020	2,020
1978-79	2,163	2,163
1979-80	2,253	2,253
1980-81	2,315	2,315

Ontario engineering schools would not be alone in curtailing graduate enrolments. At Harvard University, it has been recommended that the Graduate School of Arts and Science reduce its enrolment by approximately 20%, to be effected over a five-year period. In the words of the President's Report for 1968-69:

> The committee felt that the number of graduate students has become too large for the faculty adequately to instruct, that the need for large numbers to provide college and university teachers has become less pressing, and that the quality of our whole effort in this area could be improved by such reduction. . . .

[16]Ontario Council on Graduate Studies, *Report of the Committee on Student Financial Support*, August 1970.

[17]Lapp, *Undergraduate Engineering Enrolment Projections*, CPUO Report No. 70-1,

The demand for engineering doctorates from the Ontario schools will be about 125 a year. It takes a full-time doctoral student approximately three and a half to four years to complete his studies, and therefore at any one time the total number of doctoral students should be in the order of 450 students. The full-time master's student takes about a year and a half to complete his studies, so that the average number of full-time master's students will be about 1,400. From Table 9-10, the average annual graduate enrolment over the next ten years will be 1,900 F.T.E. students. The number of master's degree engineers entering the labour force should be about 950 a year. (In 1969, there were 441 engineering master's degrees awarded in Ontario.)

Over the ten-year period, the number of master's degrees awarded will not be affected by a mixture of full and part-time students. The same number of students will be awarded degrees irrespective of the mix, but with more part-time students a greater number can be accommodated at any one time. It was shown that 24% of all graduate students were enrolled part-time in 1969-70, and this percentage has been increasing. Since over 70% of engineering graduate students have had professional experience before returning to school, we expect greater numbers to avail themselves of part-time graduate studies when classes are programmed at more convenient hours and wider use is made of television teaching. We would encourage such a policy, particularly at universities located near the larger urban centres where there are sufficient numbers of practising engineers.

Part-time students usually pursue studies relating either directly to their employment, or to job availability as seen by the engineer with experience in the marketplace. Therefore, his field of study and class preferences should be an indicator of current market demands for engineers in industries close to universities. It can provide engineering schools with a built-in mechanism for relating instruction directly to the needs of the practising engineer.

ENGINEERING MANPOWER STATISTICS

Table 9-11 is a partial list of the Canadian sources of data used in this study.

Table 9-11

SOURCES OF DATA ON ENGINEERING MANPOWER

Government of Canada
- Department of Manpower and Immigration
- Dominion Bureau of Statistics
- Department of Industry, Trade and Commerce
- National Research Council
- Defence Research Board
- Science Council of Canada
- Economic Council of Canada

Government of Ontario
- Department of University Affairs
- Department of Education.
- Department of Trade and Development

The Profession
- Canadian Council of Professional Engineers
- Association of Professional Engineers of Ontario
- Engineering Institute of Canada
- Other professional Institutes and Societies

In addition, both universities and industry provided the study group with a wealth of information.

The most significant compilation of useful data on the characteristics of engineers is contained in the Department of Manpower and Immigration's 1967 Survey. Planners in education, industry, government and the profession need data of this kind on a regular and reliable basis in order that they may formulate plans and policies to assist in meeting their objectives. Such surveys should be conducted regularly in order to develop a pattern and to discern trends. It is important to have a knowledge of existing stocks but, in such planning, the recent flows into existing stocks are of more significance. Flow measurements require regular and periodic comparisons.

The demand figures developed in this chapter are based on the existing pool of engineers and growth rates assumed for the next ten years. Both of these factors could change significantly owing to events that cannot be foreseen at this time. For example, there could be a major shift in emphasis towards the "survival" industry — that sector related to pollution control and abatement, or an even more intense growth than we have anticipated in the service sector. New and more refined demand projections require an assessment of technological change and public opinion, as well as an evaluation of the economic and political climate prevailing at the time. Such projections are of critical importance in educational and manpower planning, and should be conducted at regular intervals, perhaps every two or three years.

Since the Canadian Council of Professional Engineers represents the profession at the national level, it is the logical body to coordinate periodic surveys and disseminate the processed data to the profession. The United States Engineering Manpower Commission of the Engineers' Joint Council performs such a task for the profession in the United States. It is funded by the sale of reports and publications, contributions from industry, and government contracts. A similar organization is needed in Canada.

Therefore, it is recommended that:

(9:2) the Canadian Council of Professional Engineers explore ways and means of establishing a permanent Canadian Engineering Manpower Commission in order to provide national and regional data on engineering manpower in Canada.

10

THE SYSTEM

INTRODUCTION

In Chapter 9 it was shown that the province's engineering schools can meet the need for engineers if there is a restructuring of existing entrance requirements. Once this occurs, the number of undergraduates should show a steady increase and by the end of the present decade will be up by more than 50%. We turn now to three questions that prompted this study.

1. Are there too many engineering schools in Ontario?
2. Can adequate provision be made for the anticipated numbers up to 1980?
3. What should be the enrolment pattern and student distribution among these schools?

The two major criteria in the light of which these questions must be considered are academic quality and instructional cost. These will be developed in order to establish a basis for determining the size of each school in the system. If Ontario is to achieve a rational pattern of engineering education, it will be necessary to establish enrolment quotas at the bachelor's, master's and Ph.D. levels. Individual institutions cannot continue to act independently in such matters — each must operate as a component of the system. Such an enrolment plan, although based on considerations of both cost and quality, will permit the assignment of specific roles to each university — areas of activity that are consistent with regional, provincial and national requirements.

COST CONSIDERATIONS IN ENGINEERING EDUCATION

We anticipate that an increasing percentage of young people in the 18-22 age group will continue to enroll in some kind of institution devoted to post-secondary education throughout

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the present decade, with a significant proportion of such students continuing their studies to the level of a master's or doctoral degree. In addition, aspirations of the academic community are high and will account for steady pressure to improve standards of quality, facilities, teaching loads, and salaries.

This has been responsible for a substantial drain on the provincial budget. However, the time is fast approaching when the demands of higher education for increasing financial support will outstrip the supply of available revenues. Taxpayers have begun to question the expenditure of our educational dollars, and to suggest that too little attention has been paid to such matters as efficiency and productivity.[1]

The magnitude of educational expenditure in Canada underscores the urgency for efficient management and control. These are formal disciplines that are elements in the execution of any plan. Successful planning is both qualitative and quantitative, and the advent of the modern computer has created a wave of enthusiasm for numerical analysis as a tool in the quantitative aspects.

Quantitative methods can be used effectively in educational planning only when the factors involved can be measured. The concept of cost/benefit applied to an investment is intellectually satisfying but we have grave doubts that it can appropriately be applied to educational planning. While costs can be measured with reasonable precision, benefits cannot — nor can all benefits be measured in the same dimensions. Yet cost/benefit ratios, rates of return and present values have such an authoritative and satisfying ring to them — they are so facile, and a simple number is so easy to remember. This is where a real danger lies. The assumptions and hypotheses underlying such simple results are often forgotten, so that biases are developed and decisions made without appreciation of the ramifications.

For educational planning purposes, benefits have been measured in terms of lifetime earnings, discounted to some base year by assuming various inflation rates. Such benefits have a meaning for the individual only if he fails to take into account the intellectual and cultural benefits derived from his education. Career decisions made solely on the basis of differential earnings comparisons would drive all students into medicine or dentistry. For society, the return based on lifetime earnings does not take into account the contribution of education to future economic growth, cultural development or the quality of life. Furthermore, the measurement of lifetime earnings must be based on survey data from cohorts that represent the full spectrum of careers resulting from any educational program. In Canada, with few exceptions, such data are not yet available.

The study group debated at length the use of cost/benefit techniques in the planning aspects of this study, and rejected them on the above grounds. Aside from the lack of complete cohort salary data, we were unable to find any way of quantifying the other less tangible benefits in terms of dollars. We have resorted to quantitative methods in many other areas in an attempt to achieve a balance with qualitative argument and the occasional arbitrary judgment.

In contrast to industry, where rising costs have been met by the adoption of automation and improved technology, education continues to be conducted in much the same fashion as it was a half-century ago. The increasing support accorded to universities over the past decade has made it possible for these institutions to add new curricula and new courses faster than the growth in enrolments could justify, and this has placed a limiting factor on their ability to concentrate effort in those areas where they might develop excellence.

It should be possible to achieve greater effectiveness in the deployment of resources by the use of business methods, and a clear statement of realistic objectives could establish the basis for formulating the necessary guidelines. A systems analysis can reveal methods whereby universities could substantially improve their returns in terms of academic distinction, and increase their output of trained engineers without any reduction of either quality or standards, and without adding to the load being carried by individual faculty members. In future, administrators, deans and department heads will have to rely more upon quantitative methods of assessing performance in order to account to government and to the public at large for the effective expenditure of funds in meeting their specific objectives.

While cost accounting in universities has not achieved any real degree of sophistication, efforts are being made to develop more refined techniques in order to measure and compare the expenditure per student in different programs, both within a university and between univer-

[1]The Economic Council's *Seventh Annual Review* states the following: "Until recent years, efficiency was largely a matter of feel and flair on the part of some dedicated educational administrators. But in the light of current and expected developments, it is important that more widespread, systematic and intensive efforts be aimed at increasing the effectiveness of these expenditures."

sities. Difficulties arise in attempting to allocate costs between undergraduate and graduate programs, lecture and laboratory work, large and small classes, teaching and research supervision, and between different departments and faculties. In evaluating any system of engineering schools, such comparisons must be based on a common method which takes into account as many factors as possible.

An attempt was made to compute unit costs (the cost per student) for the Ontario engineering schools, and this is summarized in Appendix H.[2] The cost study develops policy variables that could be used to advantage in the operation of a department or faculty. The most important variable is the average class size — defined as the ratio of the average number of students in any section to the number of faculty teaching in that section. Figure H-1 shows how unit costs decrease with an increase in the size of the average class. Other policy variables were of less significance, but have been incorporated in the calculation of unit costs.

The cost study focused on the question of economic viability, and revealed that between 600 and 1,300 undergraduate students is the optimal enrolment range where unit costs are minimal. Such numbers apply to the existing structure where most schools offer four or more separate programs. If economic viability is to be achieved in schools where undergraduate enrolments are less than 600, then fewer programs must be offered, or the curricula so structured that a relatively large proportion of classes is common to all or most programs.

The average class size of engineering schools in Ontario in 1969-70 was found to be 55 for the first year, 34 in the second, 20 in the third and fourth years, and 32 over-all (Table H-3). As can be seen in Figure H-1, the average unit cost for undergraduates was higher by about 25% than the unit cost corresponding to the suggested minimum band. A 25% cost reduction could be achieved if the over-all average class size were increased by 25%, because of the hyberbolic relationship between unit cost and average class size (Figure H-1). Most first- and second-year classes are sufficiently large already, so that much of this increase should be taken up in the third and fourth years. A 25% cost reduction could be achieved by increasing the average class size for these years to 35-40 students. The number of students per instructor will be smaller in most laboratory and tutorial classes than in lectures, so that the total number of students in a program will have to be larger than the average class size. The extent will vary, and we have chosen a figure of approximately 20% to cover the range of programs typical of engineering. This would yield a size criterion of a minimum of 40-50 engineering students graduating per year in each program.[3] Using current attrition rates, the total enrolment in all four years would have to be 200-275 students per program.

The first year usually is common to all programs, with one school (Western) having a common first and second year, and another (Carleton) having a common first three years. Guelph has developed what is essentially a one-core program with elective courses throughout all years. If there is a common curriculum for the earlier years, class sizes can be maintained at reasonable levels. However, if the smaller schools proliferate programs, excessively large classes would be required in the years common to all programs for them to balance the small classes in the latter years, and so maintain a minimum average class size.

There is an upper enrolment limit beyond which unit costs will again increase, as shown in Figure H-2. In schools where total undergraduate enrolments exceed 1,300 students, sectioning policy in the earlier years is the principal factor affecting unit costs. As a school increases in size, first- and second-year classes expand until sectioning becomes necessary, causing a sudden rise in the unit cost. Schools in the minimum band (Fig. H-2) are passing through this kind of transition where the lower-cost schools have the largest freshman classes. Thus, in successive years, class sizes for the freshman year can suddenly be reduced by as much as a factor of two. If classes are maintained close to the maximum size consistent with proper instruction, the unit cost curve would not show the well-defined minimum evident in Figure H-2. As total enrolments increase beyond 2,000 students, there appears to be a tendency to section into even smaller classes, perhaps to compensate for the feeling of anonymity some students experience in the larger universities. In very large schools, a complex administrative infrastructure develops which tends to grow out of proportion to the amount of instruction, thus affecting costs adversely.

An examination of graduate programs shows that 55% of costs arise from research supervision,

[2]The details, including an example, are covered in the source document by Ivor W. Thompson and Philip A. Lapp, *A Method for Developing Unit Costs in Educational Programs*, CPUO Report No. 70-3, December 1970.

[3]The same conclusion was reached by Dr. F. E. Terman in *Engineering Education in New York*, The State Educational Department, the University of the State of New York, Albany, New York, March 1969.

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when assisted research[4] is included, or 91% if it is excluded (Appendix H). For the province as a whole, it would appear that over a twelve-month period the average graduate student requires about 150 hours of a faculty member's time for such supervision. The cost of instruction, representing less than 10% of the total if assisted research is excluded, obviously depends on the size of graduate classes, but this influence is small when compared to the cost of graduate supervision. Consequently, in contrast to undergraduate work, the unit cost of graduate programs does not vary significantly with graduate enrolment. This applies to the average graduate program. It would appear that in universities where course-intensive master's degree programs prevail, less time is spent on graduate supervision, and hence the cost in such cases will depend more upon class size averages.

QUALITY CONSIDERATIONS IN ENGINEERING EDUCATION

While each of the factors affecting unit costs may bear a relationship to quality, they are not a direct measure of it, and hence it does not follow that higher costs mean better quality. For example while very small class sizes result in high unit costs, they do not necessarily ensure high educational quality. When classes become small, unit costs will rise unless each faculty member carries a larger work load in order to maintain a productivity comparable to that of his counterpart in a school with larger classes. In practice, unit costs vary over a wider range than do instructional loads, but in the smaller schools there is a tendency to strive for lower unit costs by stretching these loads. Such an approach leaves faculty members less time to prepare lectures and probably dampens incentive to get on with research or to get involved in professional activities. Furthermore, in a small faculty, each member is expected to teach an assortment of subjects, and undoubtedly this will include some in which he is not fully qualified.

When enrolments do expand to the point where sectioning becomes practical, quality is not necessarily best served by dividing up the large classes. It is preferable for the outstanding teacher to be given a large class rather than force some students in a smaller section to suffer under an inferior instructor. As a general principle, the maximum number of students should be exposed to leading members of the faculty and this cannot be accomplished if they teach only small classes.

We do not suggest that larger classes are always to be preferred, and there are some subjects that can only be taught in small groups; a balance is necessary, but smaller classes do not lead automatically to higher quality. The real stature of a program depends more upon the calibre of the faculty than upon the size of the classes. If outstanding teachers take on the larger classes it will permit lighter teaching loads to be assigned to these teachers, and without any loss in productivity.

In the larger schools it is possible to offer instruction in a wider variety of topics, and the student has a better opportunity to explore individual interests. This cannot be done in the smaller schools, because of the necessity to create common curricula and to restrict the number of electives. While this may appear to make it less attractive to the student from the standpoint of diversity, it should not create any disadvantage insofar as the quality of instruction is concerned.

The cost study reveals that in schools with a relatively high ratio of graduate to undergraduate students, there appears to be a tendency to divert resources into the graduate school. When relative enrolments increase at the graduate school level, a greater proportion of each faculty member's time will be devoted to graduate supervision. Less time is available for undergraduate instruction, and some schools tend to increase class sizes at the first- and second-year levels rather than provide more teachers. The presence of a graduate school should enhance the quality of the undergraduate work, by interaction among faculty, graduate students and undergraduates. However, it is essential that the commitment to the graduate sector does not become disproportionately large.

We have concluded that unit costs are not a real measure of quality. Higher undergraduate costs can result from either too small a school or an enhancement in the quality of program. A constant effort is required to ensure that the good teachers are in contact with the greatest number of students — at a minimum of cost.

A final aspect in regard to quality and size is academic viability. In any discipline there is a minimum number of faculty below which instructional and research synergisms fail to develop. The size of this "critical mass" may differ among groups, but for each discipline a minimum figure of 10-15 faculty members appears to be realistic. Academic viability lies

[4]Assisted research is money received by a department to support graduate student research over and above the amount received from operating formula income to the university. The sources vary, but most of such funds are provided by the National Research Council.

close to the heart of instructional quality, for without it an engineering school cannot attract the kind of people to give it real distinction. If the present undergraduate student/staff ratio in the Ontario engineering schools (15:1) is appropriate, enrolment of 150-225 students for each program would be required for academic viability — figures only slightly below the minimum set by cost considerations.

DEPARTMENTS AND PROGRAMS

In both Canada and the United States, engineering schools have debated the wisdom of organizing faculties according to discipline as opposed to program. Ontario universities appear to be of the opinion that the classical subdivisions or disciplines of engineering are no longer exclusive, even though they may continue to be relevant. New programs are being developed, but to date only a few, such as industrial engineering, have achieved sufficient stature to be looked upon as new disciplines. Most discussions of engineering organization lead to the concept of a matrix, with the columns representing individual disciplines, and the rows the individual programs. A student in any program will draw from all or most of the disciplines, but the faculty is organized along disciplinary lines into separate departments. The study group can see no strong reason to suggest changes in this structure.[5] The academic viability criterion suggests that any discipline or department group should contain at least ten faculty members. Students in a program associated with this discipline would receive most of their instruction from that department, particularly in the third and fourth years.

New interdisciplinary undergraduate programs can be established within the above framework, where each department provides the required service instruction.[6] Such programs are to be encouraged but should not constitute a department until classes are sufficiently large and academic viability has been achieved. Normally, such new departments should be formed from a nucleus of staff drawn from existing departments of sufficient size that they do not suffer as a result of the separation. This would be a gradual process, where a group is formed from one or more departments and then works together in the new discipline for a number of years before separating out to create a new department.

[5]Behavioural simulation studies conducted at M.I.T. showed that when a school is reorganized into widely disparate forms, it ultimately becomes re-aligned into forms where the classical disciplines are visibly distinguishable.

[6]For example, Engineering Science at the University of Toronto.

At first the class size in a new program will be relatively small. If the school is large, the impact on the average class size will be negligible, but otherwise it can be quite significant. The specialty need not involve the introduction of new classes, if it makes use of classes offered in other faculties (e.g. engineering and management, where students could enrol in existing classes in the Faculty of Business Administration). New programs introduced in this way do not seriously affect unit costs, and ultimately may increase average class sizes if such programs attract more students into the engineering school.

From the foregoing, it is possible to formulate conclusions about the best size for the Ontario engineering schools. Programs become economically and academically viable when enrolments reach a level of about 200-275 students. A department should contain at least ten faculty members. New programs should be introduced only when the average class size can be properly sustained. For Ontario schools with three or more programs, the minimum undergraduate enrolment should be 600-1,300 students. Enrolments of over 2,000 undergraduate students should be discouraged since it is probable that in an attempt to overcome dehumanizing tendencies unit costs will rise. We have said that the number of graduate students in the system should be equal to the number of bachelor graduations of the previous year. While such a relationship is meant to be applied to Ontario as a whole, we are suggesting it as a guideline for each institution, to ensure a reasonable balance between undergraduate and graduate studies. On the basis of the present attrition rates, the number of graduate students would amount to approximately 18-19% of the total undergraduate enrolment in the previous year, a figure that will vary from year to year and between institutions.

ONTARIO ENGINEERING ENROLMENT DISTRIBUTION

Total undergraduate enrolments are expected to grow from 8,500 in 1969-70 to 13,000 in 1980-81, and freshman intake should increase from 2,700 to 4,000 students over the same period (Fig. 9-4).

Table 10-1 shows the enrolment distribution for 1969-70, and the number of programs offered in that year in each school, together with the minimum size associated with these programs. The minimum size used for each program was 200 students; this figure is at the lower end of the suggested range, although it may be high for

Table 10-1

UNDERGRADUATE ENGINEERING ENROLMENTS BY UNIVERSITY, ONTARIO 1969-70

University	F.T.E. Undergraduate Enrolment 1969-70	Number of Undergraduate Programs	Minimum Viable Size	Enrolment Deficiency
Carleton	538	3	600[a]	62
Guelph	157	1	200	43
Lakehead	47	1	[b]	
Laurentian	37	3	[c]	
McMaster	528	6	1,200	672
Ottawa	368	4	800	432
Queen's[d]	1,160	6	1,200	40
Toronto	2,199	8	1,600	—
Waterloo[e]	2,349	4	800	—
Western	441	5	1,000[f]	559
Windsor	402	7	1,400	998
	8,226			2,806

a First three years are common (viable size could be smaller).
b First year only.
c First and second year only.
d Engineering chemistry, engineering and mathematics and engineering physics not included in total.
e Cooperative program.
f First two years are common (viable size could be smaller).

schools with a common curriculum beyond the first year. In considering enrolment deficiencies, it can be seen that out of the eleven schools in the system, only two are above the minimum size (Toronto and Waterloo), three are close to the minimum (Carleton, Queen's and Guelph), while the rest are well below a minimum size in relation to the number of programs being offered at the present time. On this basis it could be concluded that Ontario has more engineering programs than can be justified by any criterion other than a need for geographic distribution. Yet, in spite of this situation, new programs continue to be introduced, the need for which is highly questionable.

An almost identical situation existed in the State of California when a similar study was undertaken in 1968 by Professor Frederick E. Terman[7] of Stanford University. In his words:

> Such proliferation of curricula is a universal academic disease, and the situation that exists in California is typical even if indefensible. Many California institutions would have stronger engineering programs if they gave up some of the fields of engineering in which their enrolments are now very small and likely to remain so, and utilized the resources thus released to strengthen other areas of engineering. The Coordinating Council should give positive encouragement for such action, even to considering the possibility of exerting substantial pressure for the elimination at individual institutions of existing curricula that have been given a fair trial and have failed to develop enough following to justify their existence.

[7]F. E. Terman, *A Study of Engineering Education in California*, Coordinating Council for Higher Education, State of California, March 1968, p. 58.

Table 10-2

UNDERGRADUATE ENGINEERING PROGRAMS—ONTARIO

PROGRAM	CARLETON	GUELPH	LAKEHEAD	LAURENTIAN	McMASTER	OTTAWA	QUEEN'S	TORONTO	WATERLOO	WESTERN	WINDSOR
Chemical				X	X	X	X[b]	X	X	X	X
Civil	X		X[a]	X	X	X	X	X	X	X	X
Electrical	X		X[a]		X	X	X	X	X	X	X
Mechanical	X		X[a]		X	X	X	X	X	X	X
Metallurgy and Materials					X		X	X		X	X
Industrial								X			X
Geology				X				X			X
Mining Engineering							X				
Physics or Science					X		X[c]	X			
Agriculture Engineering		X									
and Management Systems					X[a]						
Design									X		

a Offered for the first time in 1970-71. b Including Chemistry (Engineering). c Including Mathematics and Engineering.

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Figure 10-1 — GEOGRAPHIC LOCATION OF ONTARIO ENGINEERING SCHOOLS

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Such a viewpoint can be said to apply to Ontario in the year 1970.

The specific programs offered in Ontario are shown in Table 10-2. It is apparent that coverage of subject material is adequate, and possibly more than adequate in the classical fields of chemical civil, electrical and mechanical engineering. A complete listing of degrees awarded in Ontario by institution and by discipline for the years 1961-1969 is presented in Appendix B.

The geographic distribution of the Ontario engineering schools is illustrated in Figure 10-1, which shows that the more populous regions of the province are well served. In the heavily industrialized area along the northwest shore of Lake Ontario there are no fewer than five schools within a 100-mile span, while Ottawa has two such schools. All but one of these schools are within a 220-mile radius of Toronto — a four-hour drive on good highways.

RECOMMENDED DISTRIBUTION OF UNDERGRADUATE ENROLMENTS

An examination of Table 10-1 reveals five schools where numbers are too low, and even with an anticipated build-up of enrolments (Fig. 9-4), there will not be enough students in Ontario to overcome these deficiencies, at least until after 1975. Furthermore, the distribution of enrolments will continue to be unbalanced unless steps are taken to limit the intake at certain schools, since it appears that students are being attracted to the well-established faculties, or to schools in the large urban centres. Unless the smaller schools develop to a viable size, the cost of engineering education in the province will continue to be higher than it needs to be and the quality will vary.

If the upper limit of enrolment, based on cost and academic viability, for any school is to be 2,000 undergraduates, and if by 1980 about 13,000 of them are in the system, then only seven schools would be required. But there are special regional needs, and experience has shown that it takes ten or more years to build a strong engineering school. Therefore, throughout the 1970s those schools below critical size should be preparing themselves for continuing growth into the 1980s while the others either reduce numbers or hold to present figures. There are good reasons for retaining more schools than a minimum of seven, and the smaller schools must strive to attain minimum viable enrolments as rapidly as possible. They should limit the number of their programs and develop strength around one or two specialties.

For these reasons, we shall recommend a reduction in freshman intake at Toronto and Waterloo and the establishment of an upper limit on freshman enrolments at the other schools, with the exception of Lakehead and Laurentian, for which new roles are recommended (see page 80). In this way, freshman intake will be redistributed within the system, and each school can grow to a viable size in the shortest possible time. Table 10-3 summarizes the recommended upper limits for freshman intake at each school: if undergraduate enrolment projections are correct, then by instituting the recommendations in 1971-72, these limitations should be reached in all schools by 1980. There is no justification for another engineering school in the province until after 1980, and then only if it can be introduced as a part of the total system.

Table 10-3

RECOMMENDED FRESHMAN INTAKE
ONTARIO ENGINEERING SCHOOLS 1971-1980

University	Approximate Freshman Intake 1970-71a	Recommended Maximum Freshman Intake 1971-1980	Approximate Steady State Size a. Maximum Intake b
Carleton	220	400	1,250
Guelph	47	150	500
Lakehead	48	0	300-+ c
Laurentian	46	0	0 d
McMaster	235	500	1,600
Ottawa	100	400	1,250
Queen's	373	500	1,600
Toronto	669	600	2,000
Waterloo	671	650	2,200
Western	155	400	1,250
Windsor	120	400	1,250
Totals	2,684	4,000	13,200

a As of mid-September 1970.
b Assuming attrition rates do not change appreciably from those at present.
c Recommended new two-year degree program for diploma technology graduates.
d Recommended that engineering studies be phased out by 1972.

Past enrolments for each school and recommended structures for the future are shown in graphical form in Appendix B. This pattern is based upon criteria that stem from academic considerations and operating revenue, and not on the capacity of the physical plant. Already, certain schools are limiting enrolments because of a lack of facilities (e.g. Queen's, Toronto and Waterloo). The actual pattern of future growth will depend upon the available capacity of each school. At the present time there are some with surplus space which should be filled before any facilities are extended. For this reason it will be recommended that, until the student population in the system builds up, Toronto and Waterloo restrict freshman intake to 600 and 650 students respectively, while Queen's holds at about 400 students.

No attempt has been made to undertake a quantitative assessment of the facilities required by the Ontario engineering schools; their present holdings are summarized in Appendix E. A detailed study is being conducted by the Committee of Presidents of Universities of Ontario and the Ontario Department of University Affairs on a capital formula covering all faculties. It will establish capital requirements for each type of student in the system and a mechanism for the funding of universities on an equitable basis. It is to be hoped that such a formula will make it possible to evaluate the requirements of each engineering school, and to plan its expansion and refurbishment in line with the enrolment growth patterns suggested in this report.

RECOMMENDED DISTRIBUTION OF GRADUATE ENROLMENTS

Table 10-4 shows the present enrolment distribution of the 1,893 F.T.E. graduate students in 1969-70. On the basis of the projection in Figure 9-5, it has been recommended that the total number be reduced to 1,600 by the year 1973-74. We have suggested that graduate enrolments in each institution follow essentially the same pattern as recommended for the province, and therefore the future distribution of graduate students would stem from the number of bachelor's degrees awarded.

Appendix B contains a tabulation of bachelor's degrees and graduate enrolments for the past ten years, by institution and by discipline. Figures B-2 to B-12 were constructed from these data and include total undergraduate and freshman enrolments at each engineering school. The number of bachelor's degrees to the year 1974-75 was estimated from the freshman intake using the recent attrition patterns of each school. These estimates are based on the assumption that future flow rates of diploma technology graduates into second year will not significantly alter attrition patterns, at least for the next two years. Table 10-4 lists the estimated number of bachelor degrees to be awarded at each institution in 1973, derived from Figures B-2 to B-12.

This distribution provides a reference for establishing graduate enrolment quotas for the year 1973-74, also shown in Table 10-4. Queen's University anticipates a graduate enrolment of 180 students in that year, a figure that is below the criterion derived in Chapter 9, but consistent with its present five-year plan. Numbers somewhat larger than those suggested by the guideline are recommended for Toronto and McMaster,

Table 10-4

RECOMMENDED GRADUATE ENGINEERING ENROLMENT DISTRIBUTION 1973-74

Institution	F.T.E. Graduate Enrolment 1969-70	Estimated Bachelor's Degrees Awarded 1973	Recommended F.T.E. Graduate Enrolment [a] 1973-74	Recommended Ph.D Enrolment 1973-74
Carleton	115	115	115	60[b]
Ottawa	156	90	90	
McMaster	184	120	150	45
Guelph	23	30	30	0
Queen's	168	250	180	55
Toronto	625	440	480	165
Waterloo	456	385	385	125
Western	79	90	90	0
Windsor	87	80	80	0
Totals	1,893	1,600	1,600	450

a Both master's and Ph.D. students.
b Joint program (to be recommended in Chapter 11).

particularly in view of their location in large urban areas of continuing growth, and the strength of their graduate programs (see Table 5-1).

The study group is concerned over the rapid growth of Ph D. studies in Ontario. Of the 1,893 graduate students in 1969-70, more than 600 were doctoral candidates. We have recommended that the total number of such students in the system not exceed 450 a year until this figure is updated at the next review. The recommended distribution of these doctoral candidates is listed in the last column of Table 10-4, and is discussed further in Chapter 11.

The recommended enrolment growth of the graduate schools up to 1980-81 is shown in Figure 9-5. If the number of doctoral candidates remains constant at 450, the enrolment in master's programs will grow from 1,150 F.T.E. students in 1973-74 to 1,350 in 1980-81, when about one graduate student in five would be a doctoral candidate. Over the present decade, the pattern of growth will be determined in large part by the flow of freshmen into each engineering school.

FINANCIAL IMPLICATIONS

One of the defects in formula financing is that it makes provision for financial support by sanctifying current trends without questioning whether they are desirable in the light of social needs. This has induced the universities to indulge in an almost immoral "numbers game", resulting in distortions which are now becoming apparent. For this reason, it is necessary to consider the financial impact of some of the recommendations in this report, if formula financing is to be continued in its present form.

A reasonable annual expenditure for the education of a doctoral candidate is about $17,500 ($10,000 from formula income, $7,500 of associated costs). The suggested reduction in enrolment of doctoral candidates will result in a saving of about two million dollars, some of which should be made available to assist in implementing other recommendations in this report. However, as the system now stands, the loss of formula income from operating budgets of the universities will represent hardship, rather than opportunity, as the engineering schools adjust to their newly defined roles. For this reason, the operating formula will have to be restructured if the recommendations of this report are to be implemented.

Alteration of the formula will have to be such that there can be a smooth transition from the existing structure to the developing new system. Difficulties are bound to be encountered,[8] since the present formula is retrospective in character, while our recommendations are prospective. Until there is some indication of the actual timing of the implementation of these recommendations, there is little purpose in suggesting new and less simplistic formulae. Certainly they will involve increasing the weight of the basic income unit accorded to the engineering undergraduate, with a probable decrease in that allocated for doctoral studies. We strongly recommend that: **(10:1) it is essential that changes in the formula be considered concomitantly with the development of the system.**

[8] "A problem emerges, however, if these weights are unintenionally out of line with actual unit costs, or if there is a substantial difference between average and incremental costs. In such a situation, the universities may tend to stress those programs which are overweighted in order to get extra money." Economic Council, *Seventh Annual Review*, p. 69.

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UNIVERSITIES IN THE SYSTEM

We have recommended an enrolment distribution for the system that we believe to be consistent with cost and quality considerations, and also a pattern of growth to ensure that individual schools attain viable size in the shortest possible time. This has established an external configuration which permits a more detailed assessment of the internal structure of each school in order to meet the over-all educational objectives of the system.

We have said that there appears to be no compelling reason to alter the traditional branches of engineering which have been developed over the past century. They should continue to be offered to engineering students, particularly at the long-established schools and those in large urban centres where enrolment pressures will be most severe. Therefore, we will recommend that a full spectrum of engineering programs continue to be offered at four universities. In addition, certain areas that may have been somewhat neglected in the past now demand attention and should represent focal areas of importance in the immediate future. The location of two engineering schools in the nation's capital, close to governmental research facilities, constitutes a special opportunity. We shall recommend that they be assigned a cooperative common role specializing in information systems engineering, and with a joint doctoral program making use of federal laboratories. Three others should specialize in environmental engineering, liberal engineering and agricultural engineering. In the north, there should be a new two-year program designed for graduates with a diploma in technology, to provide for regional and provincial needs. Engineering should be discontinued at one university.

In this chapter, these and other recommendations relating to the system will be developed.

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UNIVERSITY OF TORONTO

The Faculty of Applied Science and Engineering at Toronto is the oldest-established program of engineering education in Ontario. The basis for a "School of Practical Science" at Toronto was laid down in an act of the provincial government in 1873. Although originally conceived of as a separate institution, in 1906 the "School" formally became the university's Faculty of Applied Science and Engineering. Today, it has more than 15,000 living graduates, who represent nearly one-sixth of Canada's professional engineering community. The present enrolment of 2,824 ranks it as one of the largest schools on the continent, and all Canadians can take pride in its achievements and its international reputation.

The study group was impressed by the close association between engineering and the other faculties at the University of Toronto. In our visits to the universities, no other engineering school appeared to have more satisfactory interactions with other faculties in both research and teaching.

Today, this engineering school is in a position to engage in innovation as applied to teaching techniques and ways to extend the outreach of its faculty — not only to other universities, but also to the community, industry and society. It has been devoting a good deal of attention to the teaching of first-year students, and to the use of more senior and experienced members of the engineering faculty in teaching first- and second-year mathematics and science. Proposed changes in curricular patterns to be introduced by 1971-72 may well establish useful guidelines for some of the other schools. In research, cooperative projects such as the radio astronomy program with Queen's University and the transportation program with York University are commendable and should be encouraged The team approach to consulting work on the part of the Toronto faculty has had an impact on the growth of secondary industry in Canada, and the current development of entrepreneurial interest among its faculty could stimulate further "growth" industry in Ontario.

There appears to be a maximum size within which human and physical resources can be distributed efficiently and our study has shown this to be approximately 2,000 undergraduate students, which corresponds to an annual freshman intake of 600 students. (Toronto's present limit on freshman enrolment is somewhat higher than this — 669 early fall registrations in 1970 (Fig. B-9). The recommendation for graduate enrolment is 480 students, which includes 165 doctoral candidates; such levels should enable the faculty to maintain excellence.

In summary, it is recommended that:

(11:1) the University of Toronto continue to offer a full spectrum of engineering program, but that, starting in 1971, it limit freshman intake to 600 students a year, and reduce graduate enrolment to 480 students, including no more than 165 doctoral candidates by the 1973-74 academic year.

QUEEN'S UNIVERSITY

This Faculty of Applied Science is the third-oldest engineering school in the province. Undergraduate enrolment has been growing steadily and in 1969-70 there were 1,360 students (Fig. B-8). Queen's has been limiting its freshman intake over the past four years to approximately 370 students, so that total enrolments should level off at about 1,400 early in the 1970s.

Founded in 1841, Queen's is an old and well-established institution. It has an illustrious history of scholarship and service, with the threads of Scottish pragmatism and conservatism woven into the very fabric of the university. These have provided the necessary strength to overcome difficult periods in the past, and to impart to its make-up a reputation and stability shared by few other universities. The Queen's Alma Mater Society, one of the strongest in Canada, has a membership list that reads like a "Who's Who" of the builders of our nation.

These threads of conservatism are apparent in the development pattern of the Faculty of Applied Science, particularly at the graduate level. Over the past five years, undergraduate enrolment has run parallel to that of the province, but the number of graduate students has risen more slowly. Today, its graduate school enrolment is 12.3% of its undergraduate total, compared to 22.2% for the province as a whole.

While we believe the growth in engineering graduate studies should be curbed and have recommended that other schools reduce graduate enrolments, we believe graduate student numbers at Queen's should increase slightly in order to achieve its planned target of 180 by 1973-74, with no more than 55 doctoral candidates. Queen's should continue to offer the full spectrum of undergraduate programs, and at the same time its graduate school should strive to develop greater strength and stature.

The recent formation of the Canadian Institute of Guided Ground Transport is an imaginative concept, and an excellent example of cooperation between university, industry and government. The location of this university, away from the major urban centres, requires such special efforts to extend its outreach into Canadian industrial and academic life.

First- and second-year students complained that fundamental courses were taught not by engineers, but principally by members of science and mathematics departments, and further that such classes were too large. We suggest that greater attention be focused on these earlier years. The freshman intake is now limited to 370-400 students. This pattern should continue for the next five years in order to permit other schools in the system to develop, and to provide time for Queen's to answer these criticisms. Between 1975 and 1980, the freshman intake should be allowed to increase to 500, a figure consistent with the role of Queen's as one of the province's four major schools offering a broad range of engineering disciplines.

Its mining engineering program is the only full course in this field being offered in Ontario. The present shortage of such engineers suggests that this department should be given special attention. There is need for a new mining building, and we would urge that in the development of this important activity, there be additional cooperation with the Ontario mining community. In particular, we recommend that:

(11:2) a three-way cooperative program between the university, Cambrian College in Sudbury. and the mining industry in that area be thoroughly explored. Such a program could combine work experience with specialized classes in mining technology and thus provide aspiring mining engineers with a combined educational experience in a region of the province where they may be employed. (See page 80).

In summary, we recommend that:

(11:3) Queen's University continue to offer a full spectrum of engineering programs while maintaining an annual freshman intake no greater than 400 students until after 1975, and then increasing this figure to 500 students a year. Further, we recommend that engineering graduate enrolments increase slightly to 180 students by 1973-74, which would include no more than 55 doctoral candidates.

UNIVERSITY OF WATERLOO

In July 1957, the Faculty of Engineering introduced Canada's first cooperative program. It has become the largest undergraduate engineering school in the nation, with an enrolment of 2,349 students. Today, it ranks among the five largest cooperative engineering schools in North America, and this rapid growth attests to its popularity.

Undergraduates spend alternate terms in the university and in industry, and over a five-year period devote eight terms to study and six terms to industrial employment. Such a program, unique in Ontario, has proved to be a refreshing departure from the conventional pattern that prevails among the other schools in the province. Both industry and the academic community have enthusiastically endorsed the precepts underlying the cooperative system of engineering education. This requires extensive contacts with industry and other employers of engineers, and is carried out by the Department of Co-ordination and Placement, which has developed a network of employers within Ontario and throughout Canada. New cooperative programs are being introduced in other provinces, which may cut into the employment market for Ontario university students. In times such as at present, with some scarcity of employment opportunities, the market for cooperative students will become saturated. For these reasons, we recommend that:

(11:4) Waterloo continue to be the only engineering school offering a cooperative program in Ontario throughout the 1970s, and that its engineering be limited to this type of program.

Since 1960, Waterloo has experienced the highest growth rate in the system, with an increase of more than 200 students a year (Fig. B-10). At the present time, freshman intake is being limited to an average of 672 students (Table B-2), so that future growth will be restricted. We have suggested that an engineering school can become too large, and that enrolments of more than 2,000 students should be discouraged. This view was shared by a Committee of The Engineering Faculty Council at Waterloo, who reported in 1963:

> There would be little further advantage in terms of scale and efficiency in any enrolment larger than 2,000. The only possible advantage would be the ability to "cover" more specialized disciplines with the corresponding growth in faculty numbers. But this would only be achieved at the expense of increasing anonymity amongst students and members of the faculty.

It goes on to say that efforts should be directed towards improving quality among the undergraduates, and that, "while other engineering schools in Ontario operate with enrolments well below capacity, such action at Waterloo would cause no distress or suggestion of disservice to the public that supports the university."

Waterloo has been offering four undergraduate engineering programs — chemical, civil, electrical and mechanical — and now offers a new program in systems design. It is interesting to note that its objectives have been met by providing only the four basic branches of engineering without inhibiting growth.

The expansion has been equally spectacular at the graduate level. Starting with eight students in 1960-61, enrolment has risen steadily to 456 F.T.E. students in 1969-70. It is understood that the school intends to restrain further growth, so as to consolidate this effort at a level comparable to what was recommended in Chapter 10.

For these reasons, we recommend that:

(11:5) Waterloo continue to offer a full spectrum of undergraduate engineering programs, but restrict its freshman intake to 650 students. Also we recommend that by 1973-74 total graduate enrolments be reduced to 385 students with no more than 125 in doctoral programs.

Engineering at Waterloo is entering a period of relative stability when increasing attention should be focused on excellence in teaching and research. As a young school, it has little in the nature of institutional traditions that might fetter its ability to experiment and to innovate in teaching methods and research directed toward solutions to regional and national problems.

In Chapter 3 (page 10) we advocated that one engineering school in Ontario become a technical university, with its own Senate and Board of Governors. At Waterloo, the Faculty of Engineering has an opportunity to undertake such an experiment. In its formative years, as a young, large and viable faculty, it experienced little difficulty in developing and sustaining policies consistent with its goals and objectives. Now it has arrived at a consolidation phase, and the continuing growth of the university around it will tend to have a stultifying influence at a time when administrative flexibility may be crucial to its leadership and pursuit of excellence. Moreover, in its submission Waterloo suggested that a good case can be made for the setting up of a separate technical university "in view of the particular structure and attitudes in Canadian universities today".

Of course, undergraduate engineering programs must depend on other faculties for service instruction; furthermore, interdisciplinary studies and research should be a characteristic of any modern university. Engineering students have emphasized the benefits to be gained from associating with students in other disciplines. Consequently, there is need for close affiliation between the autonomous engineering school and the university in this proposed arrangement. This could be accomplished by cross-appointments in those disciplines normally associated with other faculties, and by the purchase of service teaching where cross-appointments are not practical.

We recommend that:

(11:6) the Faculty of Engineering at Waterloo undertake negotiations to enable it to be reorganized into a technical university, with a separate Board of Governors and Senate, but in affiliation with the University of Waterloo.

McMASTER UNIVERSITY

The Faculty of Engineering was established in 1957 on a firm base provided by the strong departments of physics and chemistry; it is an element in the Division of Science and Engineering. Undergraduate enrolments have grown steadily at an average rate of 42 students a year, and there were 504 undergraduates in 1969-70 (Fig. B-6). Although located in a major urban centre, it is straddled by the two largest engineering schools in the country — Toronto to the east, and Waterloo to the west. Further to the east is Queen's, and further to the west is Western, and all have had an adverse effect on the growth of McMaster's undergraduate enrolments. We have recommended a curtailment in the freshman intake at three of these schools (Queen's, Toronto and Waterloo), which should channel more freshmen into McMaster. Since Hamilton is a rapidly expanding industrial region, the commuting student population should experience a substantial growth.

McMaster offers six undergraduate programs, with two of them (metallurgy and engineering physics) in cooperation with departments in the Faculty of Science. A seventh, engineering and management, is being operated jointly with the School of Business. Such combined programs tend to enlarge class sizes and render them more economically viable.

We have recommended that Queen's, Toronto and Waterloo continue to offer a full spectrum of undergraduate programs. These schools should account for a total of 5,800 students, which is only 44% of the anticipated Ontario undergraduate enrolment for 1980. We believe a strong argument can be made for adding McMaster to this group.

The growth in McMaster's engineering graduate enrolment has been rapid: from eight graduate students in 1960-61 to 184 in 1969-70. Today,

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it is the third-largest such graduate school in the province, with a size representing 36.5% of undergraduate enrolments — considerably more than the provincial average. The vitality of its activity is well demonstrated in Tables 5-1 and 5-2.

In summary, we recommend that:

(11:7) McMaster continue to offer a full spectrum of engineering programs, while increasing its freshman intake to 500 students a year, but that by 1973-74 the number of its graduate students be limited to 150, including 45 doctoral candidates.

CARLETON UNIVERSITY

The undergraduate program at Carleton, now in its tenth year, is made up of three years of study in a common-core curriculum followed by a single year of specialization in civil, electrical or mechanical engineering. This arrangement is unique in Canada. While rigid in structure, it does make possible certain economies. The great majority of Carleton students whom we interviewed expressed satisfaction with their curriculum, and some viewed with concern the recent introduction in the second and third year of an engineering or science elective which could represent a deviation from the pattern. The present program is sound, successful and distinctive, and although course content and sequence do require a continual evolution, any dismantling of its basic structure would be a loss to the Ontario system.

The popularity of Carleton's present engineering program is reflected in the pattern of its enrolment (Fig. B-2). Although the City of Ottawa shares two engineering schools — Carleton and Ottawa — the two schools draw from constituencies that overlap only slightly. The students at Carleton are English-speaking, while the students at Ottawa are predominantly bilingual. For this reason, the alternative to Carleton tends to be Queen's, not the University of Ottawa. Queen's has maintained its freshman enrolment at a fixed level since 1965, and we have recommended that it continue this pattern. Carleton's freshman intake is rising slowly, and should continue to rise throughout the 1970s. Ultimately, an increase in undergraduate enrolments at Carleton will be limited by population growth in the Ottawa region. It is difficult to predict what this will be, but we have recommended that Carleton limit its freshman intake to 400 students a year (Table 10-4), a figure that could be reached in the present decade. Graduate enrolments at Carleton have grown more slowly but have already reached the level recommended for 1973-74 in Chapter 10. (Table 10-4).

It is unnecessary for each Ontario school to offer a full range of engineering programs as long as there is a sufficient variety of programs within the system. This has been ensured by our recommendation that Toronto, Queen's, Waterloo and McMaster continue to cover the full spectrum, maintaining faculty and departments in a broad range of disciplines. This will leave each of the remaining schools in a position where they can specialize and concentrate resources in one or two major areas — selected on the basis of regional and national needs that are not being adequately served at the present time. In this way, resources will not be spread over such a wide range of activities that effort would be unduly diluted.

In Chapter 5 (page 24) we suggested that research in the field of information systems engineering will be of paramount importance in future, and that such a role should be assigned jointly to Carleton and Ottawa universities. The proximity of government laboratories and industrial facilities serves as an added incentive to generate meaningful interaction between these institutions and the universities. Initially, work in this field should be concentrated at the graduate level, with a joint doctoral program shared by the two universities, before becoming infused into undergraduate studies. At Carleton this could occur rapidly and efficiently because of the three-year common-core curriculum. Cooperation with other agencies would be a matter for negotiation where the two universities act together.

In summary, we recommend that:

(11:8) Carleton retain its present undergraduate program structure, limit its freshman intake when it reaches a figure of 400 students a year and maintain graduate enrolment at 115 students, including 60 doctoral candidates to be shared equally with Ottawa. Further, we recommend that graduate student and faculty research be directed towards the field of information systems engineering, and that Carleton explore jointly with Ottawa ways to collaborate with local governmental and industrial laboratories, for example, by means of a talk-back television network (Chapter 4, p.16).

UNIVERSITY OF OTTAWA

Engineering at the University of Ottawa can be traced back to 1873, but the modern phase in this development began in 1946 with the offering of the first two years of a degree program. This was extended to the full four years, and in 1956, engineering degrees were awarded for the first time. Today the engineering school forms part of the Faculty of Science and Engineering.

Students divide into three nearly equal groups according to mother tongue: French, English or another language. The cosmopolitan mixture of both students and staff is a distinctive feature of the university. Undergraduates are required to be proficient in both French and English.

Four undergraduate programs are being offered — in chemical, civil, electrical and mechanical engineering. Enrolments are shown in Table B-1 and Figure B-7. In Chapter 10, we suggested that a school is neither economically nor academically viable until there are at least 200 students in a program. In 1969-70, Ottawa's total undergraduate enrolment was 369 as compared to a minimum viable number of 800 students. Even if university projections are correct, this minimum size could not be attained until 1975-76; but a decrease in the 1970-71 freshman intake over the previous year does not augur well for these projections.

It would appear that a case can be made for either reducing the number of programs offered, eliminating engineering altogether, or creating a common-core curriculum similar to the pattern developed at Carleton. The last choice is the most attractive because it presents a prospect for increased cooperation between these two schools, especially if they share a television network. The two schools have already begun to work together in civil engineering at the undergraduate level, and graduate students in each school receive credit for classes taken at the other. However, it was stated that a major impediment to further cooperation is the difference in the structure of undergraduate programs.

Ottawa graduate enrolments have more than doubled in the past two years, and have grown to a size disproportionate to that of the undergraduate school, but the arguments used in Chapter 10 led us to recommend a major reduction from 156 students in 1969-70 to 90 students by 1973-74. A joint Ph.D. program with Carleton in the field of information systems engineering was recommended, and we envisage this as the field of specialization in the Ottawa undergraduate program — as recommended for Carleton.

In summary, we recommend that:

(11:9) Ottawa create a common-core undergraduate curriculum in a pattern similar to that at Carleton; graduate enrolments be reduced to 90 students by 1973-74, including 60 doctoral candidates to be shared equally with Carleton, and graduate student and faculty research be directed towards the field of information systems engineering in a joint program with Carleton. Further, we recommend that Ottawa explore arrangements with Carleton for the installation of a talk-back television network that would include government and industrial laboratories in the area, and would serve both undergraduate and graduate programs.

We recognize the difficulties inherent in these recommendations but are attempting to establish the equivalent of a single, strong engineering school in the City of Ottawa — in effect, one unit with two branches representing the basic linguistic and cultural differences between the two institutions.

UNIVERSITY OF WESTERN ONTARIO

Western established a Department of Engineering Science in 1954, and its first degrees were awarded four years later. Undergraduate enrolments reached a figure of 442 students in 1969-70 (Fig. B-11). Many of its students are drawn from southwestern Ontario, which has a relatively stable population. However, quotas on intake recommended for the larger schools should increase the student flow from other parts of the province.

It has a common-core engineering curriculum in the first two years, with three optional streams in addition to the core studies in the second year, leading into five different programs for the two final years. At the present level of enrolment, there appears to be little justification for so many programs. Engineering experienced a drop in freshman intake for 1970-71 and this suggests that an estimate of 640 undergraduate engineering students by 1974-75 may be optimistic. Even at this level, only three programs would be viable according to the arguments developed in Chapter 10.

Graduate studies were begun in 1962, and by 1969-70 there were 79 F.T.E. students. We have recommended that this enrolment should not exceed 90 by 1973-74 (Table 10-4). Western has gained distinction with its work in industrial aerodynamics, electrostatics and bio-engineering, while its course-work M.Eng. program in environmental engineering is generating widespread interest.

Following the same pattern as proposed for Carleton and Ottawa, Western has a specific area for specialization. Environmental engineering is becoming a subject of increasing interest, and Western is in a position to concentrate in such a field. This is an exciting prospect, because of its social relevance and because of the strong desire of capable young people to play a prominent role in the solution of problems relating to our ecology. At Western, graduate student and faculty research could be adapted without difficulty and there is a strong case for the introduction of an undergraduate program in environmental engineering. This could be accomplished by developing existing options into one major program with a common-core structure. The present doctoral program should be abandoned, and no new programs developed before the end of this decade, and then only after a demand for doctorates in this field has been clearly demonstrated.

For the above reasons, we recommend that:

(11:10) Western concentrate its graduate student and faculty research in the field of environmental engineering, and that a new common-core undergraduate program be introduced in this field in place of the existing options. Further, we recommend that graduate enrolments at the master's level should not exceed 90 students by 1973-74, and that no further students be admitted to existing doctoral programs.

Western's Engineering Science Department was established at a time when there was a major shift in engineering education towards greater science content. In Canada, this is no longer a major issue, as universities attempt to focus on engineering as a distinctive profession involving a body of knowledge in which science is but one of many critical components. For this reason, we would suggest that the faculty consider deleting the word "science" and becoming the Faculty of Engineering.

UNIVERSITY OF WINDSOR

Located in the southwestern corner of the province, Windsor draws the bulk of its students from a region where the population has remained relatively stable. Since 1967, there has been a slight annual decline in freshman intake (Fig. B-12) and total undergraduate enrolment has hovered around 400 students. Growth can be expected here for the same reasons as suggested with respect to Western, and so will depend on new student flow patterns in the province as a whole.

Windsor now offers seven undergraduate engineering programs, each with a separate curriculum after the first year. In Chapter 10 we developed criteria that suggest that 1,400 students is the minimum viable size for this number of programs. It is unlikely that such enrolment can be achieved during the present decade, and therefore the arguments developed for Western apply equally to Windsor: the present number of undergraduate programs should be curtailed.

In Chapter 3 (page 10) we suggested the need for a liberal education program built around a strong core of engineering. In order to preserve the engineering ethos of such a program, the basic design disciplines must be stressed. This could be accomplished by structuring options in the major disciplines during the latter years, but their number should be consistent with viable class sizes determined by total undergraduate enrolments. Liberal engineering also has meaning in the area of graduate studies, and will accelerate the development of interdisciplinary work. Graduate enrolments were covered in Table 10-4.

In summary, we recommend that:

(11:11) Windsor establish a new undergraduate program developed around a liberal engineering core, and with an emphasis on design; and that such a program replace those now in existence. The number of design options should be consistent with viable class sizes. Further, we recommend that graduate studies be concentrated on liberal engineering and that enrolments be reduced to 80 by 1973-74, with no further work at the Ph.D. level during the present decade.

UNIVERSITY OF GUELPH

Established in 1964, the University of Guelph includes the Federated Colleges of the Ontario Department of Agriculture, one of which was the former Ontario Agricultural College. It had formed a Department of Agricultural Engineering in 1946, which provided an engineering option. Subsequently, arrangements were made with the University of Toronto whereby such students could register for the final year of mechanical engineering or civil engineering. In 1964-65, the Senate of the University of Guelph approved an academic program leading to the B.Sc. (Eng.) degree, in which students concentrate in the final year on one of three engineering majors: mechanical and power, structural, or water resources.

Further changes were effected in 1969 when a new program was introduced based upon a core concept for engineering with two elective components — one in the humanities and social sciences and the other in the life and earth sciences. Each elective represents 13% of the total curriculum, and they are interwoven into all years of the program. Such a feature, while normal for humanities and social science subjects, is a departure from the usual arrangement of structuring each option into one of the standard engineering disciplines during the latter years of a program. A common engineering component (74% — with its core of mathematics, physical

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sciences, engineering sciences and design) is combined with a wide range of options to permit each student to establish a program geared to his own interests, under the guidance of a faculty member. The majority of classes in such options will be taught by departments outside the School of Agricultural Engineering.

Such an arrangement should appeal to students who have a strong desire for greater freedom to create their own program. The basic engineering core concept is sound for a school the size of Guelph. It has reduced by 30% the total number of classes offered in engineering, and thereby increased the average class size within the school. Other optional classes may be augmented by non-engineering students. This program should be economically and academically viable provided total enrolment exceeds 200 students (as suggested in Chapter 10).

We have a reservation about the elective nature of the humanities and social sciences component. In Chapter 7 (page 35) we suggest that curricula in the "applied humanities" should be structured and form part of an engineering core, in view of the direct relevance of such subjects to the foundations of the profession. This could still allow for some elective classes, but they should be supplementary to a required group of classes in the applied humanities. Such an argument can be applied to several schools in the system, but it is particularly appropriate for Guelph because of the nature of its new curriculum.

The enrolment pattern of Guelph is shown in Figure B-3, and its recommended graduate enrolments are given in Table 10-4.

In summary, we recommend that:

(11:12) Guelph pursue its new engineering core program, with options in the life and earth sciences, but with the applied humanities added to the core. Further, we recommend that graduate enrolments not exceed 30 students by 1973-74, and no further work at the Ph.D. level be undertaken during the present decade.

THE NORTH

In addition to the nine universities already discussed in this chapter, there are two in the north — Laurentian and Lakehead — offering the first two years of a degree program in engineering. Their students must transfer to one of the nine schools in order to complete the requirements for a degree.

The region of Ontario north of Lake Nipissing has a sparse population but an abundance of natural resources. The pulp and paper industry is concentrated in the area of Thunder Bay, which is the site of Lakehead University. Mining takes place throughout the region but its centre is Sudbury, the heart of the nickel and copper belt and the location of Laurentian University.

Therefore, it is not surprising that the majority of engineers are employed in management and operations. Local chapters (Thunder Bay and Sudbury) of the APEO have provided statistics on their constituency, and the following distribution is given for the 1,200 engineers in the region:

Civil	— 33%
Mining	— 25%
Metallurgy	— 12%
Chemical	— 10%
Other	— 20%

A survey conducted by these APEO chapters reveals that approximately 900 new engineers will be required during the next ten years, assuming there will be a major development of natural resources. It suggests that the distribution of the disciplines will continue to be the same as at the present time. If this requirement is spread uniformly over the decade, then the approximate requirements for engineers will be as follows:

Civil	— 30 a year
Mining	— 22 a year
Metallurgy	— 11 a year
Chemical	— 10 a year
Other	— 17 a year

It has proved difficult to attract engineers into the north. In the Sudbury region, nearly 70% are from outside Canada, and there is a high turnover. In the pulp-and-paper-oriented Thunder Bay district, more than 75% of the engineers have family roots there, and fewer than 10% come from abroad. There appears to be a continuing shortage of engineers in both areas, and this was the basis of the argument in favour of establishing engineering schools at Laurentian and Lakehead universities.

At Laurentian, 86% of the engineering students are from the region, while at Lakehead 60% come from the immediate district, 20% from the rest of the northern area and 20% from elsewhere. Thus, it can be seen that both engineering schools are essentially local in nature.

Students who elect to leave home to attend university are more likely to be attracted to the larger urban centres in the province. This has been established by the study group in tracing the origins of students in such universities as Toronto and McMaster, and confirmed by the Ontario Institute for Studies in Education in its studies of student flows. On this basis, it is meaningful to examine grade 13 student flows from the high schools within commuting range of these two northern universities, because it is from these schools that they would draw more than half of their engineering students.

Table 11-1

GRADE 13 ENROLMENTS IN HIGH SCHOOLS WITHIN A 35-MILE RADIUS OF LAURENTIAN AND LAKEHEAD UNIVERSITIES

	1968	1970 (estimated)	1980 (estimated)	Engineering Freshmen a 1970	Engineering Freshmen a 1980
Laurentian	794	965	2,000	68	140
Lakehead	698	850	1,800	60	126

a Assuming 7% of grade 13 enrolments enter engineering, a figure that is high for the 1970s (Ontario average expected to be 6%).

In Table 11-1 it is assumed that the commuting radius for each university is 35 miles, and also that a slightly higher percentage of high school students than the Ontario average will enter engineering. Many of these freshmen, not wishing to commute, will elect to go elsewhere to university. We have assumed that 50% leave the area, and the remainder will comprise one-half the total number of freshmen in the north. The validity of this assumption rests on the anticipated continuing desire for students to leave home to study in the larger urban centres, and on the present enrolment patterns at these two universities. Thus, the number of engineering freshmen shown in Table 11-1 is a rough approximation of the first-year enrolment in each school for the years 1970 and 1980. In actual fact, early first-year registration in September of 1970 was 40 at Laurentian and 48 at Lakehead, so that estimates for 1970 were high by 70% and 25% respectively.

These engineering schools have been in existence for more than a decade, and yet the numbers of freshmen in degree programs have remained in the 15-62 band for Lakehead (Fig. B-4) and 0-44 for Laurentian (Fig. B-5). Unquestionably, the necessity to transfer after two years to another university has been a deterrent to first-year enrolments. Such two-year "semi-programs" satisfy neither students nor staff, and can only be justified as an interim measure during the emergence of a new faculty. Now it is time for programs at both schools to be either extended or terminated. If they were extended to four years, Table 11-1 suggests that neither school could reach a viable size until the late 1970s for even one program in a single discipline (freshman intake of 90-100 students). In the meantime, students and staff would continue to suffer from insufficient enrolment as other engineering schools attract the top students from the region. The temptation would be strong to adopt lower standards of entrance, and it is hard to avoid the conclusion that it would be advisable to terminate these programs.

LAURENTIAN UNIVERSITY

There is a continuing shortage of mining engineers in the Sudbury district, and industry has been forced to search for them in other provinces and outside Canada. Queen's University offers the only mining engineering program in Ontario, in which it has been awarding fewer than 10 bachelor's degrees a year. Since the current demand for the north alone is approximately 22 a year, there is now more student interest in this field, and the new mining building at Queen's will enhance the development of one of Ontario's primary industries. In 1970, graduates with bachelor degrees in mining were being offered the highest starting salaries of all branches of engineering in Ontario: $692 a month, compared to the over-all average for engineering of $656 a month[1]

Next to mining, there is a growing demand in the Sudbury region for metallurgical engineers. Over the past decade the number of new baccalaureates in this field from the Ontario schools has averaged 25 a year and the need in the north is expected to be about 11 in each year of the present decade. Such engineers are used in many other industries, and it is possible that we will experience a continuing shortage until the program at McMaster expands. Most metallurgical and materials engineers in Ontario now come from Queen's or Toronto. Programs required for the north in other fields (principally civil and chemical engineering) are in abundance.

The existing Ontario schools should be able to provide engineers of the required disciplines to satisfy the special needs of the Sudbury region. Furthermore, even if Laurentian could fully satisfy the regional demand for engineers, local industries have indicated that they do not wish to restrict recruiting to a single university, and so will continue to draw upon traditional sources of supply for new engineering graduates.

Laurentian has only four faculty members in

[1]Department of Manpower and Immigration, *Requirements and Average Starting Salaries, University Graduates, 1970.*

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engineering, and limited facilities. The university maintains that there is insufficient space to accommodate the proposed expansion to a four-year program, and therefore it would be forced to adopt some form of a trimester cooperative program with local industry. To date, such plans have not been developed.

For all of these reasons, it is recommended that:

(11:13) the existing engineering programs at Laurentian University be terminated, and no freshmen be admitted for 1971-72.

All students presently enrolled should be given the opportunity to complete their course of study, which means work in engineering should not cease until June 1972. This should provide sufficient time for the university to organize the most effective way in which to re-deploy valuable resources, and to work out plans with members of staff for alternative careers. In the event that the university decides to discontinue engineering in 1971, provision must be made to subsidize the education of those students affected in order that they may complete their second year at another institution.

In our discussions with local industries, it was apparent that they are anxious to assist the university. International Nickel provided most generous financial support towards the construction of buildings at Laurentian, and indicated an interest in continuing assistance in those areas of direct relevance to the company. We would suggest that any such support should be directed towards the development of geology and other related earth sciences, including geophysics.

Cambrian College, the College of Applied Arts and Technology in Sudbury, offers three-year diploma courses in chemical, civil, electrical, geological, metallurgical and mining technology. These were designed to satisfy the needs of local industry, but have assumed increasing importance because of the present shortage of mining and metallurgical engineers which has resulted in technologists being hired to undertake tasks normally performed by graduate engineers. We believe there is much to be gained in three-way cooperation between Cambrian College, the Department of Mining Engineering at Queen's University, and the mining industry in the Sudbury district. Mining technology classes could be developed at Cambrian which would enable Queen's students to gain practical experience in the local industry. In this way, students would be exposed to the industry early in their careers, and industry would be given an opportunity to attract these students prior to graduation. The details of any such cooperative plan would require considerable negotiation, and we would hope that local industry might take the initiative in setting up such an arrangement.

LAKEHEAD UNIVERSITY

There will be a continuing demand for engineers in the pulp and paper industry of the Thunder Bay district and a requirement to meet the needs of a small but growing number of manufacturing plants. The city of Thunder Bay is situated at the edge of the boreal forest region of Canada within the mid-Canada corridor. It is likely to be a major growth centre in any program to develop Canada's north. Figure 10-1 shows that Thunder Bay is isolated from the more heavily populated areas of the province. Its inhabitants still retain a frontier outlook -- a "spirit of the north" which is infectious, and many who come intending to stay for but a short time are caught up in its atmosphere and settle there permanently.

There is a pressing need for more people and especially for engineers. It is unlikely that northern development will be a major focus for the expenditure of public money in the near future because of the higher priority being accorded to urban problems. Nevertheless, governmental projects relating to the region should increase in intensity towards the latter half of the 1970s, when the demand for engineers could become even more acute than it is at the present time.

There are valid reasons for developing a program at Lakehead University which will attract potential engineers into the region at the stage in their lives when they are about to make career decisions and other long-term commitments. The present two-year program fails in this respect because it sends them away two years before graduation. On the other hand, a regular four-year program would not be viable until late in the 1970s or early in the 1980s. Lakehead also offers three-year programs leading to diplomas in technology and the first year of architectural technology. It is the only such school in the province where degree and diploma students are taught in the same institution. The viability of any four-year degree program, which depends principally on the number of bachelor graduations in each discipline, would not be altered appreciably by the presence of such programs in technology.

The recent expansion of the CAATs has meant a growing number of diploma technology graduates in Ontario. It has been estimated that about 15% of these graduates have both the desire and the ability to pursue further studies towards a bachelor's degree in engineering. Some of them are being admitted to established degree programs, usually at the second-year level. A significant number have proceeded into the third year of engineering degree programs in the United States, and many remain there permanently following graduation.

The Ontario engineering schools have not structured any programs specifically for these diploma technology graduates. Usually such students are behind in basic mathematics and science, but ahead in technology-related subjects. The study group is convinced that with a reorganization in the presentation of subject material, a diploma technology graduate could achieve the necessary academic qualifications for a bachelor's degree in engineering after a further two years of full-time study. By this route, education to the baccalaureate degree in engineering normally would take five years from grade 12, the same number of years as for graduates of university programs. Such programs would differ from the present third and fourth year in that they must stress basic mathematics and science. A student with a technology background approaches these subjects in a different light, because usually he has a keener appreciation of the application of this basic material to the real world.

The Ryerson Polytechnical Institute has announced its intention to provide a degree program for diploma technology graduates. While details have not been revealed at the time of writing, we believe such a program would appeal to technologists employed in the heavily industrialized section of the province who look for the opportunity to work on a part-time basis towards an accredited degree.

It has been stated by those in charge of the CAATs that they have no intention of establishing degree programs, that their programs are terminal in nature and should not be considered as a preparation for university work. Therefore, such programs as those proposed for Lakehead and planned by Ryerson should develop without competition. Many diploma technology students will not elect to return to school immediately after graduation, and for this reason, it is difficult to estimate potential enrolments. The third year of technology enrolments in the CAATs has grown from 570 in 1967-68 to 774 in 1969-70,[2] and this pattern should continue throughout the 1970s. At Ryerson the third year of technology also has developed rapidly, increasing from 464 in 1967-68 to 739 in 1969-70, but this growth is levelling off. Enrolments at Lakehead for this new program have been estimated conservatively at 300 students by the late 1970s, provided it is established and under way within the next two years. It would make possible the offering of bachelor's degrees in three disciplines: chemical (pulp and paper), civil, and mechanical or electrical engineering. The university has ample facilities for such a program.

[2]D.B.S. Tables (unpublished material) completed and revised by H. Braithwaite of the Ontario Institute for Studies in Education in August 1970.

A separate study[3] is being conducted on relationships between Lakehead University and Confederation College, the CAAT in Thunder Bay. While its recommendations are not known at this time, we believe there is merit in combining diploma and degree students in at least one institution in Ontario. This could improve the long-term relationships between technologists and engineers, particularly when there is an increasing need for an understanding of their relative roles and functions in a technological society.

In summary, we recommend that:

(11:14) the present engineering programs at Lakehead University be terminated by admitting no freshmen after 1970-71. Beginning in 1971 or 1972, Lakehead should establish a two-year full-time engineering degree program specifically designed to accommodate diploma technology graduates. The disciplines offered should be related to the needs of the district. In addition it should continue to offer existing diploma courses in technology.

YORK, TRENT AND BROCK UNIVERSITIES

We have recommended that engineering be continued at ten of the provincially-assisted universities and have attempted to show that they can adequately cover the anticipated needs of Ontario over the present decade. By 1980, it is hoped that each of these schools will be economically and academically viable. Moreover, since they are spread geographically across the province, all major regions will be served by them. We have recommended changes in the engineering curricula of some of these schools in order that proper coverage may be provided for those major technological areas which we foresee as being of importance to the future of the province. Therefore we recommend that:

(11:15) no further engineering schools be established prior to 1980.

[3]Commission on Post-Secondary Education in Ontario.

York University, located in Toronto, has a Faculty of Science which is developing several imaginative new concepts. Among them is a liberal science program with some of the characteristics of the liberal engineering program recommended for Windsor. Another is the Division of Natural Science which has programs in science structured for non-science students. At the present time, York is reviewing the area of applied science which is seen as filling a gap between the traditional engineering schools and the faculties of pure science.

In industrial research and development, no clear distinction is made between the applied scientist and the engineer, and often they perform identical roles. However, their education is fundamentally different. Design is the central theme or ethos of an engineering education, with the basic component being decision-making. Although science is an essential ingredient, it is not an end in itself. Engineering curricula are relatively more structured to satisfy the basic requirements of the profession, while the applied scientist requires a relatively unstructured curriculum so that he may pursue his scientific interests without severe constraints. This is the basic difference: the engineering school seeks to serve both the individual and the profession, while a school of applied science is designed to serve the individual.

York can achieve a high reputation in applied science since it has the necessary staff and facilities. However, there is no justification for another engineering school in Ontario, and therefore we recommend most strongly that:

(11:16) York devote its ambitions, energies and resources not to engineering but to applied science.

Trent University, located in the City of Peterborough in central Ontario, was established in 1963. It has been stated that the University has no intention of entering the field of engineering and we would endorse this stand in recommending that:

(11:17) no school of engineering be established at Trent during the present decade.

Brock University, located in the city of St. Catharines in the Niagara peninsula, was established in 1964. Although it has indicated a possible desire to embark upon work in engineering, it has no plans to do so at the present time. As with York and Trent, we would recommend that:

(11:18) no studies in engineering be undertaken at Brock during the present decade.

In Ottawa, we recommended that a closed-circuit television talk-back system be installed between Carleton and Ottawa universities, which should involve local governmental and industrial laboratories. We would be remiss if we did not urge a similar arrangement in Metropolitan Toronto, between York and Toronto universities together with major industries in the surrounding area including the Sheridan Park Research Centre. The extension of such a system westward to include McMaster University would be a logical next step. Ultimately, the network could be linked with the television system now being developed for engineering education in the State of New York, where there is an indication of interest in Canadian participation.

ROYAL MILITARY COLLEGE OF CANADA

There is one other engineering school in the province which has been considered, though it is national in scope, with its total financial support provided by the federal government. The Royal Military College of Canada (RMC) was founded at Kingston in 1876, and Royal Roads near Victoria, British Columbia, was established in 1942 as a training school for naval officers. Following World War II, both colleges were constituted as the Canadian Services Colleges to provide a joint educational and training program for the Canadian Armed Forces. A third college, Collège Militaire Royal, was opened at Saint-Jean, Quebec, in 1952 in order to provide for the bilingualism required in the armed forces. The Canadian Services Colleges became known as the Canadian Military Colleges on promulgation of the Canadian Forces Reorganization Act in 1968.

The program for both RMC and Royal Roads is of four years' duration, with the first two years being provided at both colleges, and the third and fourth years at RMC only. For officer cadets entering Collège Militaire Royal, the program is of five years' duration, with the final two years at RMC.

The Royal Military College is an affiliate member of CPUO even though it is not being funded by the Ontario government. It wished to be included in this study, and so completed the questionnaire and was visited by members of the study group. The composition of its student body makes it a national college. Each graduate is required to devote a minimum of four years to military service following graduation, and approximately 60% elect to remain beyond that period. However, while RMC graduates do not enter directly into the civilian labour force, ultimately many do join the profession in Ontario and we have devoted our attention to some curricular aspects of their program. After careful consideration, it was decided not to include RMC in most of the statistics since the data were being compiled to assist in planning an interactive system of provincially-assisted engineering schools.

Some distinguishing features of the RMC program are as follows:

(1) The student/staff ratio is very low (4.7:1)

(2) The officer cadet experience is unique and involves a higher workload than is found in the other universities;

(3) There is a commendable content of humanities and social sciences (25%);

(4) Officer cadets receive an allowance, and so there is less economic strain;

(5) Athletics and physical training are compulsory (15%);

(6) The college is not coeducational;

(7) New cadets have been carefully screened and the attrition rate is low;

(8) Graduates must undertake four years of military service;

(9) All students reside on campus.

In its visits to engineering schools in the United States, the study group was impressed with the programs of two schools of similar character — the Thayer School of Engineering of Dartmouth College in Hanover, New Hampshire, and Harvey Mudd College at Claremont, California. These are liberal engineering schools which emphasize the applied humanities, while at the same time laying great stress on design, using a team approach to real industrial situations. The favourable student/staff ratio at RMC suggests it could develop a similar program, using design problems related to the Canadian Armed Forces. RMC is in an excellent position to pioneer in the area of liberal engineering, because of the disciplined nature of the college, its strength in the humanities and social sciences and the generous funding it receives from the federal government.

Too few students are seeking admission to the college even though it has obvious financial advantages and a balanced athletic and academic program. Therefore, we would hope that a new curriculum, based on the liberal engineering concept, would appeal to young men throughout Canada, and so help in overcoming an apparent reluctance at the present time to embark on a military career.

Therefore, we recommend that:

(11:19) the Royal Military College develop a liberal engineering program, based on the successful model now in operation at Dartmouth and Harvey Mudd.

To sum up: we have recommended that among the fourteen provincially-assisted universities in Ontario, ten schools carry on work in engineering. This number will be adequate to cover both the needs of the province and its contribution to national requirements during the decade. No further expansion will be necessary until at least that period of time has elapsed

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RETROSPECT AND PROSPECT

It is on the eve of publication that an author is most acutely aware of the limitations and imperfections of his work. Once the commitment to print is irrevocable, the agonies of hindsight tend to fade. In this report on engineering education, the study group clearly recognizes the compromises that have had to be made. Our recommendations fall short of being Utopian because we have been dealing with a system — or rather a non system — on which have been invested very considerable amounts of time, effort and money, occasionally influenced by political expediency. A compromise with time has had to be made, because modern engineering is being buffeted by the onrush of change in technology and in the role of the engineer in society. An imperfect report now is more useful than a polished retrospective document several years hence. Inherent lags in the educational process impart a sense of urgency, and so we go to press with the realization that more could have been said, more fluently, but later.

A considerable debt is owed to all those people who have contributed to the study — in particular the faculty and students who provided data on which this report is based. If our effort is judged to be worthwhile, it is hoped that similar studies of other disciplines will be undertaken. Engineering has been a good place to begin, because it is inherently "mission-oriented", and one can develop logistics relating the needs of a modern society to the number of practising engineers within it. Such an approach is more difficult with non-professional education, but there are a number of signs indicating that the lack of appropriateness of the educational experience is troubling many students and some teachers in the humanities and the social sciences. It is probable that the need for a similar study in other areas is just as acute as for a report in the field of engineering.

The prospect of continuing rapid change dictates the need that this report be but the forerunner of a series of periodic updating studies which should be carried out at regular intervals. There is a temptation to suggest that such a task be the responsibility of the Committee of Ontario Deans of Engineering, but already it is a heavily-loaded affiliate committee of CPUO. It seems more reasonable to suggest the collection and collation of data be carried out by the CPUO Research Division. However, it should be the responsibility of the Committee of Ontario Deans of Engineering to ensure that the form of such data is uniform throughout all of the faculties of engineering, and moreover that it is compatible with the collection and retrieval system adopted by CPUO. Data should be collected on a continuing basis to meet four principal objectives:

(1) academic planning;

(2) manpower planning;

(3) cost assessment and control;

(4) program appraisal and accreditation.

ACADEMIC PLANNING

The forecasting of enrolments is critical to successful planning of the use of capital resources, as well as to the establishment of sound policies for the future. Enrolment forecasting involves the development of student flow patterns from secondary school into the universities, and within each university among its several programs and many classes. Viewed in retrospect, the questionnaire used in this study (shown in Appendix I) contained a number of deficiencies. For example, Table 5 should have requested more detail on the origin of students, in particular the location of the high school of graduation for Ontario students and the distribution of university preferences in their application for admission. The collection of such data, on a yearly basis, should enhance the ability of each school to forecast its future flow patterns. CPUO has proposed the formation of a data bank[1] that would include most of the required information.

It is recommended that:

(12:1) CODE coordinate the collection of information, as a pilot project, for a data bank to be established by CPUO.

The information that has been gathered for this study would be a starting point, and each year further refinements could be introduced into such an on-going program. Other faculties would come "on stream" in future years as they are ready to participate in it.

[1]CPUO Research Division, *Proposal for a Central Data Bank on Students and Resources of Ontario Universities*, November 1969.

MANPOWER PLANNING

We have advocated that educational planning in the engineering schools be related to the requirement for engineers in the economy, as defined both by short-term demand and long-term need. The flows of engineers into the labour market are only partially understood, and yet a knowledge of these flows is essential if one is to attempt any meaningful prediction of shortages or future career patterns. It is surprising that so few universities in Ontario maintain alumni records that trace the career histories of their graduates. Aside from any manpower considerations, such records would be most valuable for many other purposes, including the planning of future academic programs.

We recommend that:

(12:2) each school develop a technique for tracing the career histories of its graduates, and maintain records for its own use and for use in manpower studies.

COST ASSESSMENT AND CONTROL

The cost study (Appendix H) suggests there are a number of policy variables that can be used to assess and control the unit costs of each program. In the future, such considerations will assume increasing importance. The cost study conducted by CPUO and the study group covered only the one year, 1969-70. Such costs assume greater meaning when collected and averaged over several years, so that trends can be seen and individual anomalies in any one year are not overemphasized. The proposed data bank will contain only some of the information required to compute unit costs, and therefore cost assessment and control would be a private matter for each university. The annual class-size survey being conducted by CPUO will give some indication of over-all costs, but not individual program costs.

We recommend that:

(12:3) each engineering school undertake its own annual unit cost study, in order that trends may be detected and policies established for the continuous assessment and control of costs.

PROGRAM APPRAISAL AND ACCREDITATION

In Chapter 7, we recommended that CODE play a central role in the appraisal of new programs and the accreditation processes being conducted by the profession. The proposed CPUO data bank will contain information on staff and facilities that should be of considerable assistance in such procedures by decreasing the administrative load on individual faculties and departments. There may be information required that is not at present planned for the data bank (e.g. library facilities). Therefore, it is recommended that:

(12:4) CODE assess the information to be collected for the CPUO data bank, and recommend to CPUO what additional data should be assembled to facilitate program assessments and accreditations.

It is our hope that the Committee of Presidents of the Universities of Ontario will regard this report as a working document for the evolution of a system of engineering education. Virtually any of these recommendations can stand alone and are suitable for individual implementation, but the title of Chapter 10 is not accidental.

We began this report with an examination of the expectations of a young man or woman aspiring to an engineering career. The most eloquent elucidation of student concern was quoted in Chapter 3: "It is attitude rather than content, style rather than subject matter, and the system rather than the course, that are the causes of student despair." The bulk of this study has been devoted to an examination of attitude, style, and the need for a system. We sincerely hope it will assist Jean and his/her colleagues to become good professional engineers, who will play significant roles in their complex, evolving society.

RECOMMENDATIONS

The study group recommends that:

(2:1) beyond senior mathematics the secondary school Honour Graduation Diploma should be a sufficient requirement, set at a level of performance decided upon by the faculties of engineering, who must become increasingly dependent on their own evaluation of secondary schools in their districts, and upon the anecdotal reports of the principals.

(3:1)innovative opportunity in the form of design should be brought into first-year engineering programs, despite the elementary character of the design examples. The gain in motivation and morale would amply repay the expenditure of time.

(3:2) each engineering school undertake a study of its teaching laboratories, and establish ways in which the students will use them to obtain design experience.

(3:3) universities establish a depreciation policy with respect to engineering laboratory equipment, so that before it becomes obsolete or worn out, adequate reserves are generated for replacement.

(3:4) Each faculty should have a standing committee on curriculum, with substantial student representation, whose responsibility it is to ensure that there is an articulated sequence of courses in each stream. Such a committee should regard as its prime function the continuous monitoring and updating of the curricular system.

(4:1) a talk-back television network in Ottawa be thoroughly explored.

(4:2) a report be prepared for Ontario similar to that prepared by Allen M. Cartter, dealing with graduate education in the United States.

(5:1) The criteria of acceptability of graduate degrees in engineering should be recast in order that a thesis based on design or systems synthesis may be suitably assessed. This could involve the establishment of a new degree at the doctorate level.

(6:1) "We feel that both universities and industries should recognize this activity as part of the career structure of their senior staff, and joint appointments should be increased as far as possible. We would hope that in time there would be at least one joint appointment in each department, certainly in those relevant to industry."

(7:1) the universities introduce part-time undergraduate studies as an acceptable alternative path to a recognized bachelor's degree in engineering, and that when this scheme is fully operative, the present APEO examination system be terminated.

(7:2) periodic requalification (perhaps every five years) be initiated so as to require successful completion of a course of study in either control or management, or a combination of these two, together with a structured program in applied humanities.

(7:3) CODE undertake the appraisal of proposed new undergraduate programs, using essentially the same procedures employed by OCGS in regard to new graduate programs. Also, CODE should evaluate the need for each new program with respect to academic, cost and manpower considerations. In regard to such appraisal, CAB should participate so as to avoid unnecessary duplication and permit simultaneous accreditation.

(7:4) CAB re-accreditation, requested and/or approved by APEO, be coordinated through CODE, which ultimately should be in a position to provide the required quantitative data.

(7:5) all engineers engaged in teaching in Ontario be registered members of the profession.

(9:1) over the next two years the estimated graduate enrolment of 2,000 for 1970-71 be reduced by 17%, after which graduate enrolment should be equated to the previous year's bachelor graduations.

(9:2) the Canadian Council of Professional Engineers explore ways and means of establishing a permanent Canadian Engineering Manpower Commission in order to provide national and regional data on engineering manpower in Canada.

(10:1) it is essential that changes in the formula be considered concomitantly with the development of the system.

(11:1) the University of Toronto continue to offer a full spectrum of engineering programs but that, starting in 1971, it limit freshman intake to 600 students a year, and reduce graduate enrolment to 480 students, including no more than 165 doctoral candidates by the 1973-74 academic year.

(11:2) a three-way cooperative program between the university, Cambrian College in Sudbury, and the mining industry in that area be thoroughly explored.

(11:3) Queen's University continue to offer a full spectrum of engineering programs while maintaining an annual freshman intake no greater than 400 students until after 1975, and then increasing this figure to 500 students a year. Further, we recommend that engineering graduate enrolments increase slightly to 180 students by 1973-74, which would include no more than 55 doctoral candidates.

(11:4) Waterloo continue to be the only engineering school offering a cooperative program in Ontario throughout the 1970s, and that its engineering be limited to this type of program.

(11:5) Waterloo continue to offer a full spectrum of undergraduate engineering programs, but restrict its freshman intake to 650 students. Also we recommend that by 1973-74 total graduate enrolments be reduced to 385 students with no more than 125 in doctoral programs.

(11:6) the Faculty of Engineering at Waterloo undertake negotiations to enable it to be reorganized into a technical university, with a separate Board of Governors and Senate, but in affiliation with the University of Waterloo.

(11:7) McMaster continue to offer a full spectrum of engineering programs, while increasing its freshman intake to 500 students a year, but that by 1973-74 the number of its graduate students be limited to 150, including 45 doctoral candidates.

(11:8) Carleton retain its present undergraduate program structure, limit its freshman intake when it reaches a figure of 400 students a year and maintain graduate enrolment at 115 students, including 60 doctoral candidates to be shared equally with Ottawa. Further, we recommend that graduate student and faculty research be directed towards the field of information systems engineering, and that Carleton explore jointly with Ottawa ways to collaborate with local governmental and industrial laboratories, for example, by means of a talk-back television network.

(11:9) Ottawa create a common-core undergraduate curriculum in a pattern similar to that at Carleton; graduate enrolments be reduced to 90 students by 1973-74, including 60 doctoral candidates to be shared equally with Carleton, and graduate student and faculty research be directed towards the field of information systems engineering in a joint program with Carleton. Further, we recommend that Ottawa explore arrangements with Carleton for the installation of a talk-back television network that would include government and industrial laboratories in the area, and would serve both undergraduate and graduate programs.

(11:10) Western concentrate its graduate student and faculty research in the field of environmental engineering, and that a new common-core undergraduate program be introduced in this field in place of the existing options. Further, we recommend that graduate enrolments at the master's level should not exceed 90 students by 1973-74, and that no further students be admitted to existing doctoral programs.

(11:11) Windsor establish a new undergraduate program developed around a liberal engineering core, and with an emphasis on design; and that such a program replace those now in existence. The number of design options should be consistent with viable class sizes. Further, we recommend that graduate studies be concentrated on liberal engineering, and that enrolments be reduced to 80 by 1973-74, with no further work at the Ph.D. level during the present decade.

(11:12) Guelph pursue its new engineering core program, with options in the life and earth sciences, but with the applied humanities added to the core. Further, we recommend that graduate enrolments not exceed 30 students by 1973-74, and no further work at the Ph.D. level be undertaken during the present decade.

(11:13) the existing engineering program at Laurentian University be terminated, and no freshmen be admitted for 1971-72.

(11:14) the present engineering program at Lakehead University be terminated by admitting no freshmen after 1970-71. Beginning in 1971 or 1972, Lakehead should establish a two-year full-time engineering degree program specifically designed to accommodate diploma technology graduates. The disciplines offered should be related to the needs of the district. In addition, it should continue to offer existing diploma courses in technology.

(11:15) no further engineering schools be established prior to 1980.

(11:16) York devote its ambitions, energies and resources not to engineering but to applied science.

(11:17) no school of engineering be established at Trent during the present decade.

(11:18) no studies in engineering be undertaken at Brock during the present decade.

(11:19) the Royal Military College develop a liberal engineering program, based on the successful model now in operation at Dartmouth and Harvey Mudd.

(12:1) CODE coordinate the collection of information, as a pilot project, for a data bank to be established by CPUO.

(12:2) each school develop a technique for tracing the career histories of its graduates, and maintain records for its own use and for use in manpower studies.

(12:3) each engineering school undertake its own annual unit cost study, in order that trends may be detected and policies established for the continuous assessment and control of costs.

(12:4) CODE assess the information to be collected for the CPUO data bank, and recommend to CPUO what additional data should be assembled to facilitate program assessments and accreditations.

APPENDICES

A STUDENT OPINIONS

B ENGINEERING ENROLMENTS AND DEGREES AWARDED

C SOME COMMENTS ON TELEVISION-LINKED CLASSROOMS

D SPECIAL RESEARCH FACILITIES

E ESTIMATED EQUIPMENT INVENTORIES: FACULTIES OF ENGINEERING

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J STUDY VISITS

The University of Western Ontario, London 72, Canada

Faculty of Engineering Science

October 20, 1970

Dean R. M. Dillon
Faculty of Engineering Science
The University of Western Ontario
London 72, Canada

Dear Dean Dillon:

Re: The visit of the Committee of Presidents of Universities of Ontario Study on Engineering Education, April 28, 1970.

You may recall an opinion which I expressed, during the visit of the Committee of Presidents, which was based on my experience of the"Laval Exchange". I understand that you were instrumental in developing this program and I think it was a milestone in the development of Engineering Education.

At the meeting of April 28, I pointed out what I thought were some of the benefits:

- contact with French-Canadian engineering students (and vice-versa) even for those not participating directly.
- an opportunity for participants to get a conversational and technical knowledge of our other language.
- an opportunity to appreciate our entire Canadian culture.

To me, the fostering of the "Laval Exchange" is the most important problem in the development of engineering education in Canada.

I feel the interchange of engineering students between French and English speaking schools should be extended from British Columbia to Newfoundland and should be supported by tax dollars. Moreover, I feel such an undertaking can be extremely successful if undertaken with the attitude of accepting two Canadian cultures. Finally, I believe that the greatest benefits will be the favourable experiences of bicultural engineers filtering down through all walks of life in Canada.

When I expressed these ideas to the committee on April 28, there was not a large group of students present but, I recall, all those who were present, both from Laval and Western, approved in general.

Although these suggestions need much more thought and discussion, I hope you will consider them as serious and realistic proposals for the development of engineering education.

Sincerely yours,

Michael Hogan

Michael Hogan
Ph.D. Candidate

MH/re

APPENDIX A

STUDENT OPINIONS

The following paragraphs are excerpts from a paper entitled "Women in Science and Engineering — The Lost Resource" written in March 1970 by Miss A. Majorins, a second-year student in chemical engineering at McMaster University.

In this age of rapidly advancing and changing technology, where there is a shortage of manpower in the scientific fields, we find that female enrolment and female employment in scientific and technological fields remains very low. There is a reluctance to admit that there is a terrible waste of potential talent in the lack of women in science.

Most often girls who are technically minded and whose interests lie in mathematics and science are steered towards other fields which are not as demanding, but are more suited to the woman. It may be noted that almost as many girls show basic mathematical and technical aptitudes as do their male counterparts. The term *technical* aptitude, is not to be confused with the term *mechanical*. Women are naturally less mechanically minded, this being brought about by our environment; the rules being that little girls play with dolls and little boys play with trucks and building blocks. Technical aptitude is not the same. It involves mathematical and analytical ability, as well as an interest in chemistry and the natural sciences. Here the gap closes. A test in an American high school showed that 6.3% of the boys and 4.2% of the girls had aptitude for engineering.[1] This implies that women could make up 40% of all engineers — quite a bit more than the mere 1% of today and more than enough to solve the engineering shortage in the next decade.

Early conditioning by both parents and teachers, those from whom she needs special understanding and encouragement, contributes to this low enrolment, as does the lack of information on opportunities in engineering and some sciences.

* * *

A woman entering the scientific professions undoubtedly encounters obstacles and barriers along the way. The traditional role of a woman in society is one major factor. Society has differentiated between what is to be considered a woman's work and what is a man's. This may lead to a false conclusion; that science is not for the woman. Society has also imposed certain character and behaviour patterns for both girls and boys.

* * *

The possibility of entering a scientific profession does not enter a girl's mind until she is in the final years of high school. The conditioning should come earlier, say in the first years of high school or final years of junior high.

A girl, if she pursues a career in science or engineering, is said to be "different". Women students whose thoughts are science-oriented would feel more comfortable if a greater number of women entered their student ranks, and that they did not feel, as often is the case, that they are thought of as "social oddities" because of their career choices. As a result they run the risk of restricted opportunities for comfortable social relationships with other men and women.[2] A woman engineer, doctor or scientist would like to feel responsible for her individual performance as an engineer, doctor or scientist, not as a female engineer, doctor or scientist.

* * *

A professional woman should be competent in her profession. Her commitments, entering a scientific career, are the same as those of a man. In technical, scientific, or administrative matters, sex differences should not be introduced. Each problem will require the same ability and objectiveness in its solution. There is no set way of approaching a problem. Engineering involves social problems which need both feminine and masculine solutions.

* * *

To add to the Canadian statistics, data from a Department of Manpower and Immigration Survey of Professional Manpower conducted in 1967 showed that there was a total of 33,344 people employed and residing in Canada, who stated their main field of employment was engineering. Membership in Engineering Associations in Canada is approximately 60,000 today. Of the total stated above, 35 were indicated as female. The distribution among various disciplines were as follows: Aeronautical, 1; Chemical, 6; Civil, 12; Electronics, 6; Geological, 2; Industrial, 3; Mechanical, 2; Metallurgical, 2; Surveying, 1.

Women now make up a smaller percentage of the total number of professional and semi-professional workers than before. This is due mainly to the fact that the number of male workers has increased very rapidly. The number of women in professional and semi-professional jobs has not risen proportionally with the total number.

* * *

[1] Popper and Herbert, "What You Should Know about Women Engineers", *Chemical Engineering*, September 11, 1967, p. 170.

[2] *Women and the Scientific Professions*, M.I.T. Symposium on American Women in Science and Engineering, edited by J. A. Mattfield and C. G. Van Aken (Cambridge, Massachusetts: the M.I.T. Press, 1965), p. 52.

Her mobility in job location will be limited by commitments to her husband, if she is married. Even if mobility is possible, her commitments to herself as well as to her husband will make her examine closely the effects of her career decisions on their happiness. A husband should show the same considerations for his wife's thoughts. A girl wanting to pursue a career in science will have to face the fact that it will require unique concentration. There will be a demand for a more dominant place in the life than work in a less dynamic field.

• • •

Professional women are likely to marry men within their own or closely related fields. Women are from three to four times more likely to be single.[3] Although educational attainment bears no relationship to the marital status of men, it can be shown that the number of married women decreases with each degree beyond the bachelor's.[4]

• • •

[3] *Ibid.*, p .72.
[4] *Ibid.*, p. 73.

Some women have found the answer in work that can be done at home — the analysis of technical literature, translation of technical writings or free-lance writing. Others have taken part-time jobs as laboratory demonstrators, research assistants, lecturers, technicians or supply teachers.

• • •

Many men feel instinctively that engineering is a male field and that it defeminizes a woman. There is little justification for this, for no longer can the engineering profession be identified as a masculine one. No longer is the image of an engineer one of a bridge- or dam-builder wearing the notorious hard hat. Today more and more engineers spend their time in offices and air-conditioned laboratories, analyzing problems and doing product research and development. They analyze human needs and design appropriate products and processes. Women have different views on human needs than do men. Therefore both can contribute significantly to the engineering profession.

APPENDIX B

ENGINEERING ENROLMENTS AND DEGREES AWARDED

PROVINCIALLY-ASSISTED UNIVERSITIES IN ONTARIO

Table B-1

Total Undergraduate Engineering Enrolments by Institution: 1960-1969

Provincially-Assisted Universities — Ontario

UNIVERSITY	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70
Carleton	129	164	175	200	254	302	416	475	517	538
Guelph	49	36	31	26	36	113	126	142	145	157
Lakehead[a]	86	90	81	95	110	137	147	132	146	158
Laurentian	15	10	3	—	9	32	44	40	44	51
McMaster	131	140	212	248	276	294	419	435	502	504
Ottawa	123	126	130	118	174	181	205	256	337	369
Queen's[b]	749	793	794	786	824	962	1,050	1,134	1,236	1,360
Toronto	1,657	1,409	1,300	1,406	1,540	1,599	1,827	2,072	2,226	2,199
Waterloo[c]	438	641	789	1,076	1,242	1,542	1,594	1,907	2,101	2,349
Western	182	228	223	244	257	279	293	285	356	442
Windsor	152	186	198	208	214	244	285	346	393	401
Totals	3,711	3,823	3,936	4,407	4,936	5,685	6,406	7,224	8,003	8,528

a Including engineering degree and technology programs but excluding architectural technology.
b Including geological sciences, chemistry (enginering), mathematics and engineering, and physics(engineering)).
c Excluding pre-engineering and fifth year (1960-61 to 1963-64).

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Table B-2
FRESHMAN ENGINEERING ENROLMENTS BY INSTITUTION: 1960-1969
PROVINCIALLY-ASSISTED UNIVERSITIES — ONTARIO

UNIVERSITY	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70
Carleton	40	66	77	87	109	125	206	189	187	201
Guelph	—	—	—	—	—	35	42	49	47	61
Lakehead[a]	80	86	78	95	108	134	128	115	140	109
Laurentian	15	10	3	—	9	32	44	26	34	26
McMaster	72	75	83	33	107	116	217	178	185	192
Ottawa	53	40	57	42	80	78	86	105	123	127
Queen's	238	248	254	232	240	360	362	374	356	372
Toronto	403	378	420	509	529	481	652	765	766	605
Waterloo[b]	182	220	370	509	539	688	628	689	604	693
Western	93	100	77	89	95	110	124	116	162	177
Windsor	52	72	65	72	67	86	104	146	145	119
Totals	1,228	1,295	1,484	1,718	1,883	2,245	2,593	2,752	2,709	2,682

a Including engineering degree and technology programs.
b Excluding pre-engineering (1960-61 to 1963-64).

Table B-3
ENGINEERING F.T.E. GRADUATE ENROLMENTS BY INSTITUTION: 1960-1969
PROVINCIALLY-ASSISTED UNIVERSITIES — ONTARIO

UNIVERSITY	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70
Carleton	—	—	2	17	16	16	64	92	113	115
Guelph	12	11	11	11	17	23	27	22	22	23
McMaster	8	18	26	61	88	95	118	152	191	184
Ottawa	14	26	34	52	45	46	58	66	115	156
Queen's	47	63	74	84	84	73	104	125	140	168
Toronto	206	213	229	250	313	347	420	553	587	625
Waterloo	8	11	30	54	116	190	277	343	433	456
Western	—	—	4	13	17	17	30	51	75	79
Windsor	—	6	6	16	27	44	59	79	89	87
Totals	295	348	416	558	728	851	1,157	1,483	1,765	1,893

Table B-4
ENGINEERING F.T.E. GRADUATE ENROLMENTS BY DISCIPLINE: 1960-1969
PROVINCIALLY-ASSISTED UNIVERSITIES — ONTARIO

DISCIPLINE	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70
Aerospace	26	34	42	46	50	52	49	59	74	83
Agriculture	12	11	11	11	17	23	27	22	22	23
Chemical	45	53	59	107	135	167	199	256	327	335
Civil	66	70	81	99	144	176	246	322	375	411
Design	—	—	—	—	—	7	14	17	20	23
Electrical	60	87	114	147	167	195	295	367	414	463
Environmental	—	—	—	—	—	—	—	8	21	15
Geology	16	17	24	23	20	10	13	16	18	27
Industrial	—	—	—	16	26	30	33	45	39	43
Management Science	—	—	—	—	—	2	9	25	36	33
Mechanical	46	44	48	60	97	114	178	236	289	314
Metallurgy and Materials	22	25	32	45	68	70	84	96	113	104
Mining	2	7	5	4	4	5	10	14	17	19
Totals	295	348	416	558	728	851	1,157	1,483	1,765	1,893

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Table B-5
ENGINEERING BACHELOR'S DEGREES BY INSTITUTION: 1961-1969
ONTARIO

UNIVERSITY	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	AVERAGE BACHELOR'S DEGREES PER YEAR
Carleton	18	24	30	24	29	49	50	58	68	39
Guelph	21	17	16	11	14	18	22	28	26	19
McMaster	25	28	27	32	17	47	52	49	58	41
Ottawa	13	15	20	21	16	31	23	34	65	26
Queen's	203	180	142	120	161	149	153	166	238	168
Toronto	426	387	331	306	257	301	345	342	339	340
Waterloo	—	52	98	101	115	147	140	213	268	126
Western	20	21	26	39	42	50	47	47	47	38
Windsor	—	—	31	39	41	36	37	54	61	33
Totals	726	724	721	693	722	828	869	991	1,170	
RMC	26	63	64	82	90	76	75	95	69	71

Table B-6
ENGINEERING BACHELOR'S DEGREES BY DISCIPLINE
PROVINCIALLY-ASSISTED UNIVERSITIES — ONTARIO

DISCIPLINE	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	AVERAGE BACHELOR'S DEGREES PER YEAR
Chemical[a]	119	107	91	104	123	128	147	193	236	139
Civil	135	137	130	120	145	168	139	190	203	152
Electrical	139	136	166	178	165	191	220	239	259	188
Mechanical	128	153	147	138	132	173	182	204	284	171
Engineering Science[b]	99	103	102	88	89	64	66	60	57	81
Mining and Geology	35	24	24	13	12	17	16	15	26	20
Metallurgy and Materials	22	14	23	20	26	31	34	24	33	25
Industrial	28	33	22	21	16	38	43	38	46	32
Agriculture	21	17	16	11	14	18	22	28	26	25
Totals	726	724	721	693	722	828	869	991	1,170	

a Including engineering chemistry.
b Including engineering physics, and mathematics and engineering.

Table B-7
ENGINEERING MASTER'S DEGREES BY INSTITUTION
PROVINCIALLY-ASSISTED UNIVERSITIES — ONTARIO

UNIVERSITY	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69
Carleton	—	—	1	1	16	15	22	15	5
Guelph	3	3	5	8	5	5	16	16	12
McMaster	—	3	5	8	15	23	33	32	43
Ottawa	3	1	9	6	10	11	11	15	19
Queen's	25	36	37	33	31	47	23	28	30
Toronto	60	88	51	72	90	99	98	125	169
Waterloo	4	1	10	19	24	44	79	99	103
Western	—	—	—	2	2	13	8	14	31
Windsor	—	—	5	5	16	18	22	20	29
Totals	95	132	123	154	209	275	312	364	441

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Table B-8

ENGINEERING MASTER'S DEGREES BY DISCIPLINE
PROVINCIALLY-ASSISTED UNIVERSITIES — ONTARIO

DISCIPLINE	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69
Chemical	15	16	20	24	31	41	42	71	75
Civil	25	34	32	43	53	64	85	75	111
Electrical	21	16	29	30	52	65	71	101	101
Mechanical	13	19	15	19	32	51	45	46	65
Metallurgy	3	13	11	8	6	23	23	15	28
Mining and Geology	6	16	7	5	5	8	8	6	5
Agriculture	3	3	5	8	5	5	16	16	12
Industrial	—	—	—	5	6	7	9	9	10
Environmental	—	—	—	—	—	—	—	8	18
Aerospace	9	15	4	12	19	11	13	17	16
Totals	95	132	123	154	209	275	312	364	441

Table B-9

ENGINEERING DOCTORAL DEGREES BY INSTITUTION
PROVINCIALLY-ASSISTED UNIVERSITIES — ONTARIO

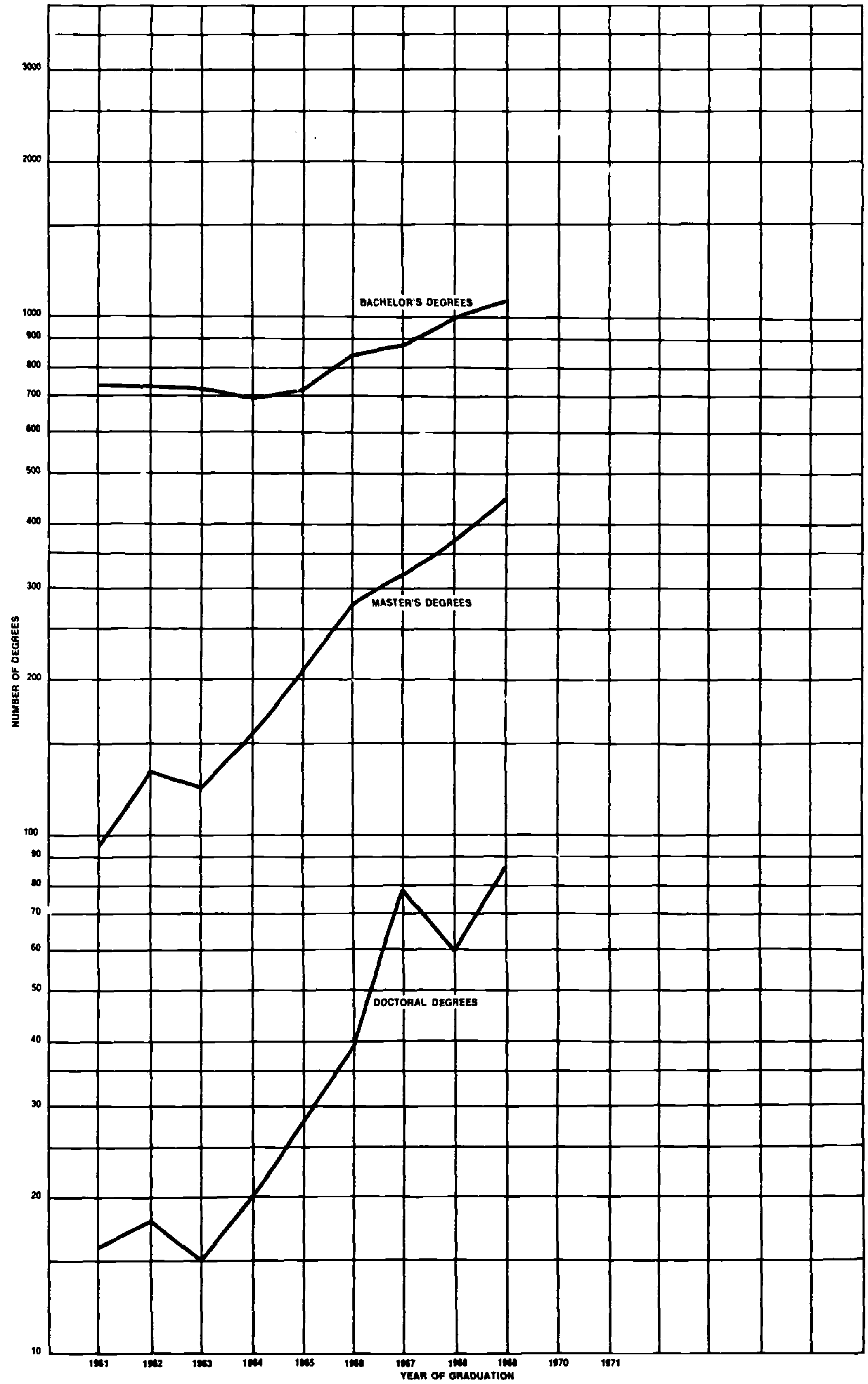
UNIVERSITY	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69
Carleton	—	—	—	—	—	1	1	3	3
Guelph	—	—	—	—	—	—	—	—	1
McMaster	—	—	—	—	—	2	4	10	6
Ottawa	1	—	—	2	3	1	6	4	5
Queen's	1	4	1	4	2	7	5	2	9
Toronto	14	14	12	13	20	23	46	26	31
Waterloo	—	—	2	1	2	5	15	14	28
Western	—	—	—	—	—	—	—	—	1
Windsor	—	—	—	—	1	—	1	1	3
Totals	16	18	15	20	28	39	78	60	87

Table B-10

ENGINEERING DOCTORAL DEGREES BY DISCIPLINE
PROVINCIALLY-ASSISTED UNIVERSITIES — ONTARIO

DISCIPLINE	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69
Chemical	6	4	4	3	4	11	13	11	21
Civil	3	3	2	3	2	9	15	12	16
Electrical	2	—	1	5	6	7	7	13	21
Mechanical	—	4	4	1	2	2	14	9	15
Metallurgy	3	1	2	2	8	3	10	11	5
Mining and Geology	1	2	—	2	1	1	4	—	—
Agriculture	—	—	—	—	—	—	—	—	1
Industrial	—	—	—	—	—	2	2	2	2
Aerospace	1	4	2	4	5	4	13	2	6
Totals	16	18	15	20	28	39	78	60	87

Figure B-1 – ENGINEERING DEGREES – ONTARIO
PROVINCIALLY-ASSISTED UNIVERSITIES



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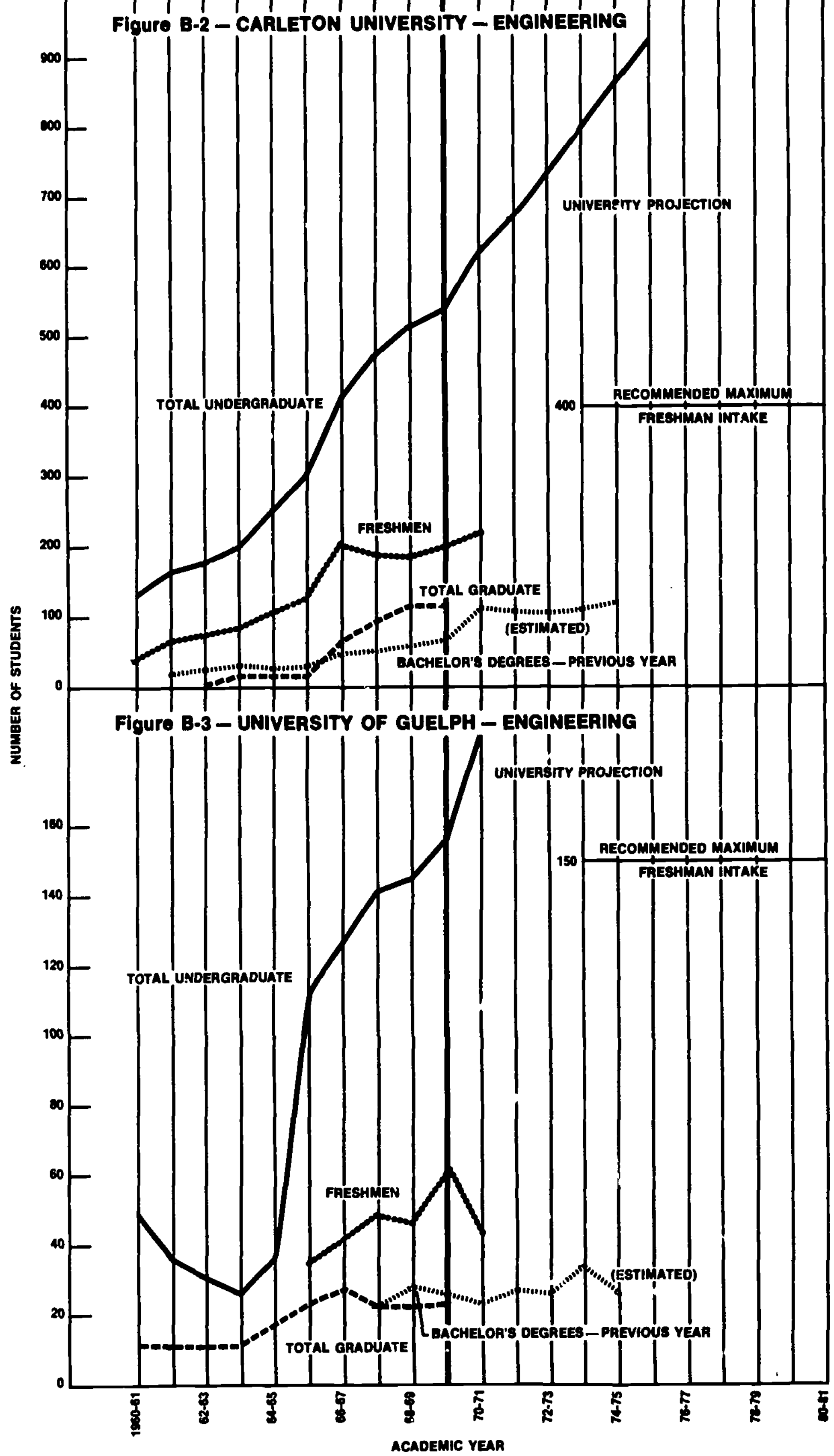

Figure B-2 — CARLETON UNIVERSITY — ENGINEERING
NUMBER OF STUDENTS
900
800
700
600
500
400
300
200
100
0
UNIVERSITY PROJECTION
TOTAL UNDERGRADUATE
400
RECOMMENDED MAXIMUM
FRESHMAN INTAKE
FRESHMEN
TOTAL GRADUATE
(ESTIMATED)
BACHELOR'S DEGREES — PREVIOUS YEAR
Figure B-3 — UNIVERSITY OF GUELPH — ENGINEERING
UNIVERSITY PROJECTION
160
140
120
100
80
60
40
20
0
150
RECOMMENDED MAXIMUM
FRESHMAN INTAKE
TOTAL UNDERGRADUATE
FRESHMEN
(ESTIMATED)
BACHELOR'S DEGREES — PREVIOUS YEAR
TOTAL GRADUATE
1960-61
62-63
64-65
66-67
68-69
70-71
72-73
74-75
76-77
78-79
80-81
ACADEMIC YEAR

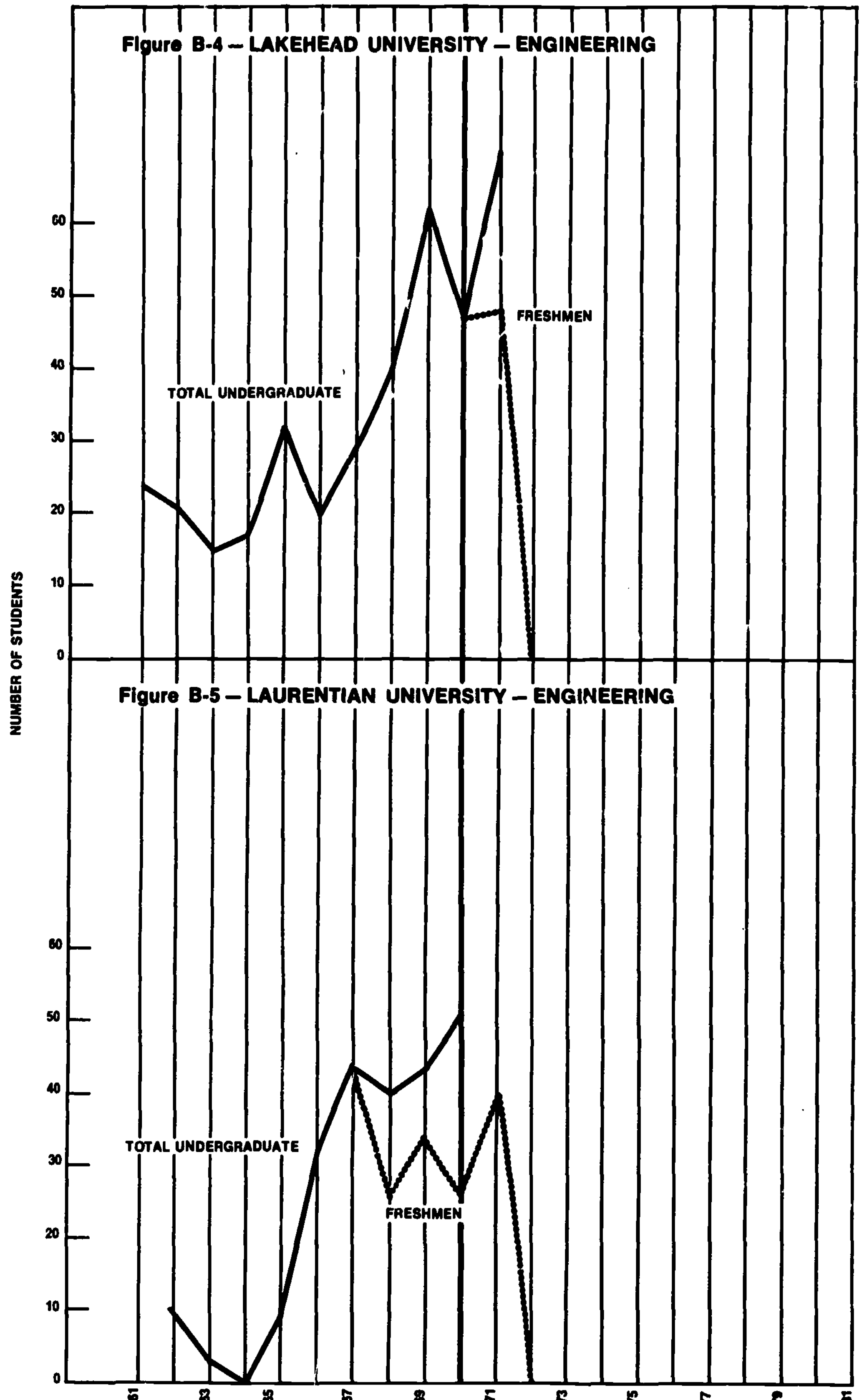

Figure B-4 — LAKEHEAD UNIVERSITY — ENGINEERING

Figure B-5 — LAURENTIAN UNIVERSITY — ENGINEERING

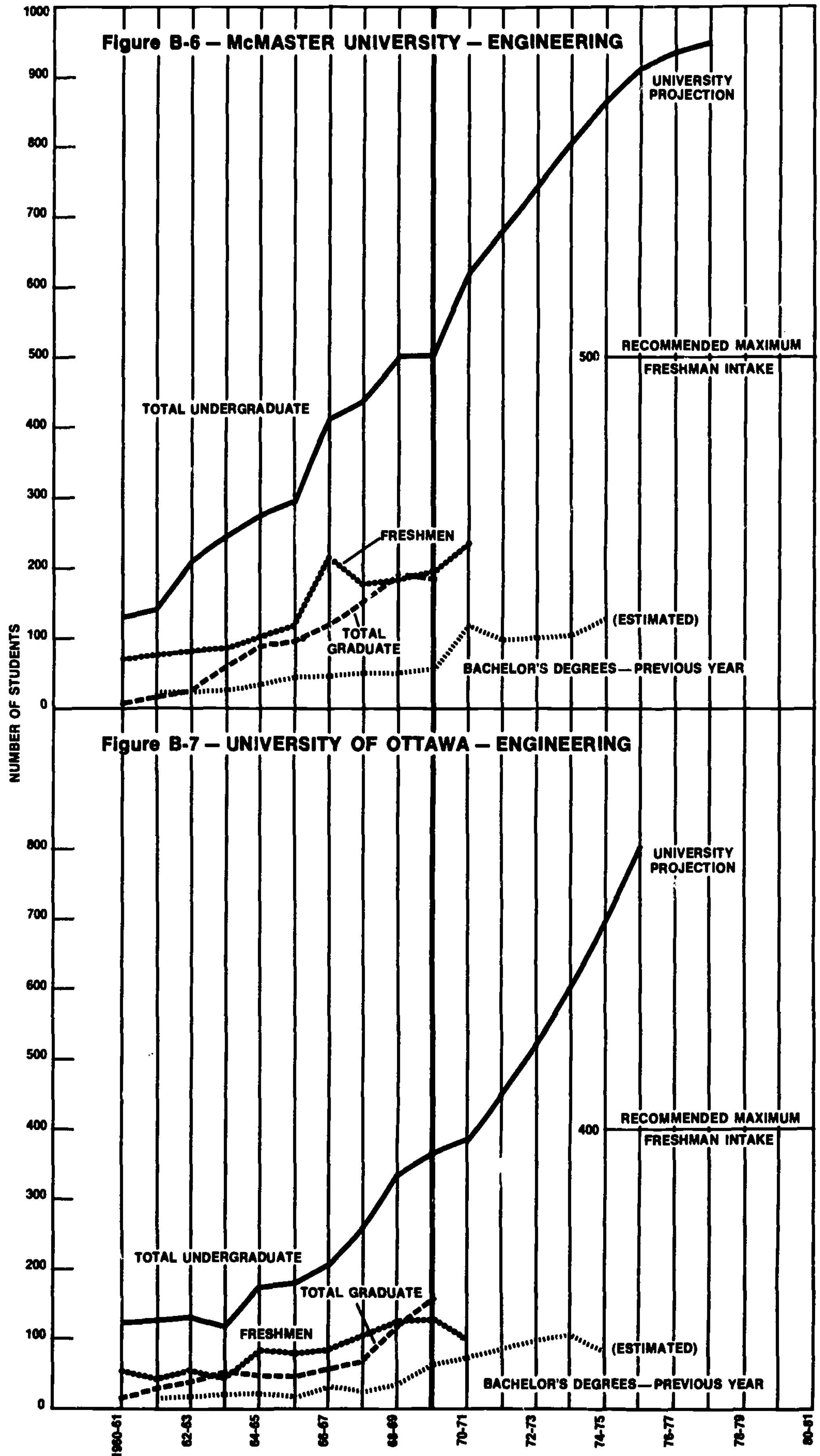

Figure B-6 — McMASTER UNIVERSITY — ENGINEERING
UNIVERSITY PROJECTION
500
RECOMMENDED MAXIMUM
FRESHMAN INTAKE
TOTAL UNDERGRADUATE
FRESHMEN
(ESTIMATED)
TOTAL GRADUATE
BACHELOR'S DEGREES — PREVIOUS YEAR
NUMBER OF STUDENTS
1000
900
800
700
600
500
400
300
200
100
0
Figure B-7 — UNIVERSITY OF OTTAWA — ENGINEERING
UNIVERSITY PROJECTION
400
RECOMMENDED MAXIMUM
FRESHMAN INTAKE
TOTAL UNDERGRADUATE
TOTAL GRADUATE
FRESHMEN
(ESTIMATED)
BACHELOR'S DEGREES — PREVIOUS YEAR
800
700
600
500
400
300
200
100
0
1960-61
62-63
64-65
66-67
68-69
70-71
72-73
74-75
76-77
78-79
80-81
ACADEMIC YEAR

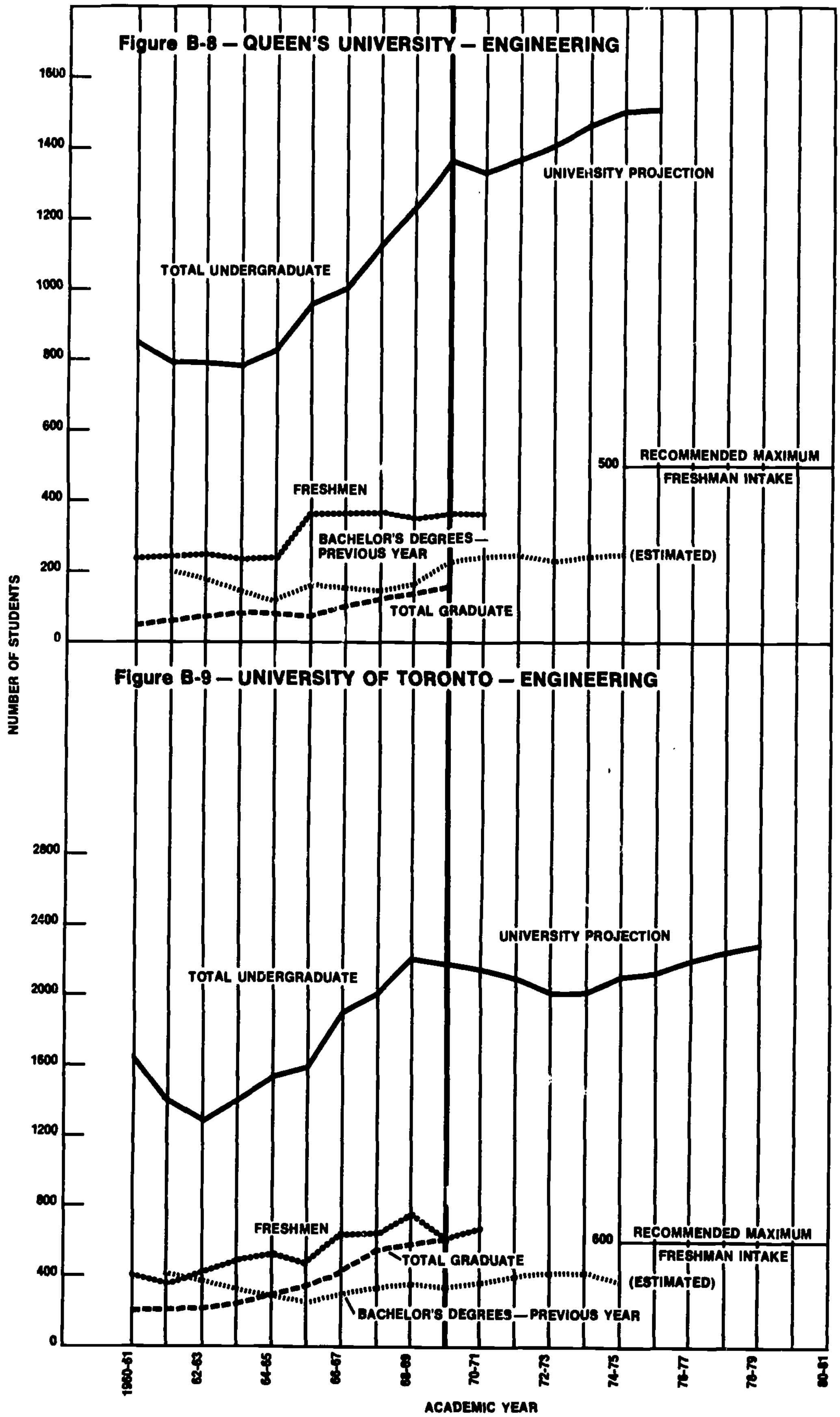

Figure B-8 — QUEEN'S UNIVERSITY — ENGINEERING
UNIVERSITY PROJECTION
TOTAL UNDERGRADUATE
RECOMMENDED MAXIMUM
FRESHMAN INTAKE
500
FRESHMEN
BACHELOR'S DEGREES — PREVIOUS YEAR
(ESTIMATED)
TOTAL GRADUATE
Figure B-9 — UNIVERSITY OF TORONTO — ENGINEERING
UNIVERSITY PROJECTION
TOTAL UNDERGRADUATE
FRESHMEN
TOTAL GRADUATE
600
RECOMMENDED MAXIMUM
FRESHMAN INTAKE
(ESTIMATED)
BACHELOR'S DEGREES — PREVIOUS YEAR
NUMBER OF STUDENTS
ACADEMIC YEAR
1960-61
62-63
64-65
66-67
68-69
70-71
72-73
74-75
76-77
78-79
80-81

114

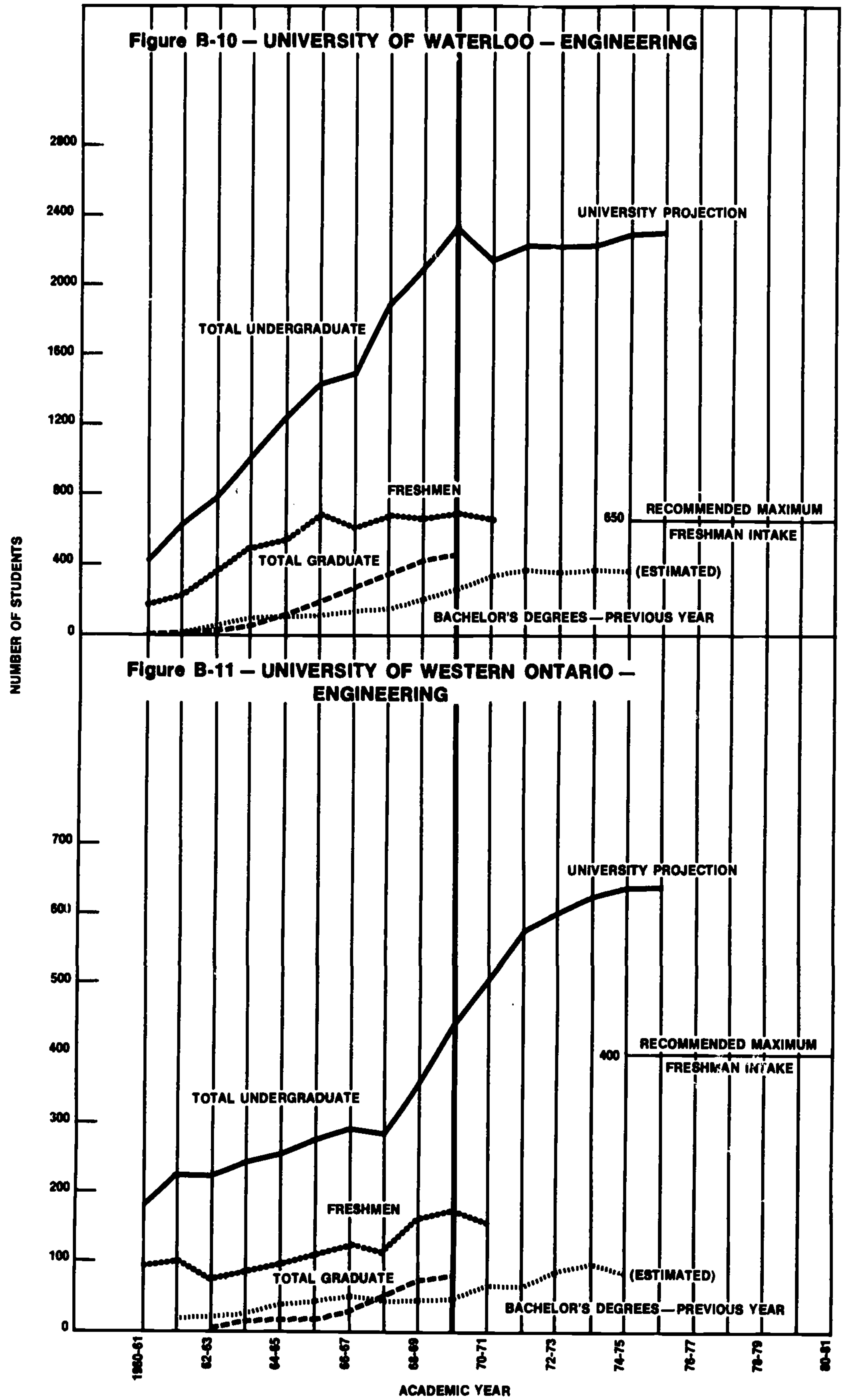

Figure B-10 — UNIVERSITY OF WATERLOO — ENGINEERING

Figure B-11 — UNIVERSITY OF WESTERN ONTARIO — ENGINEERING

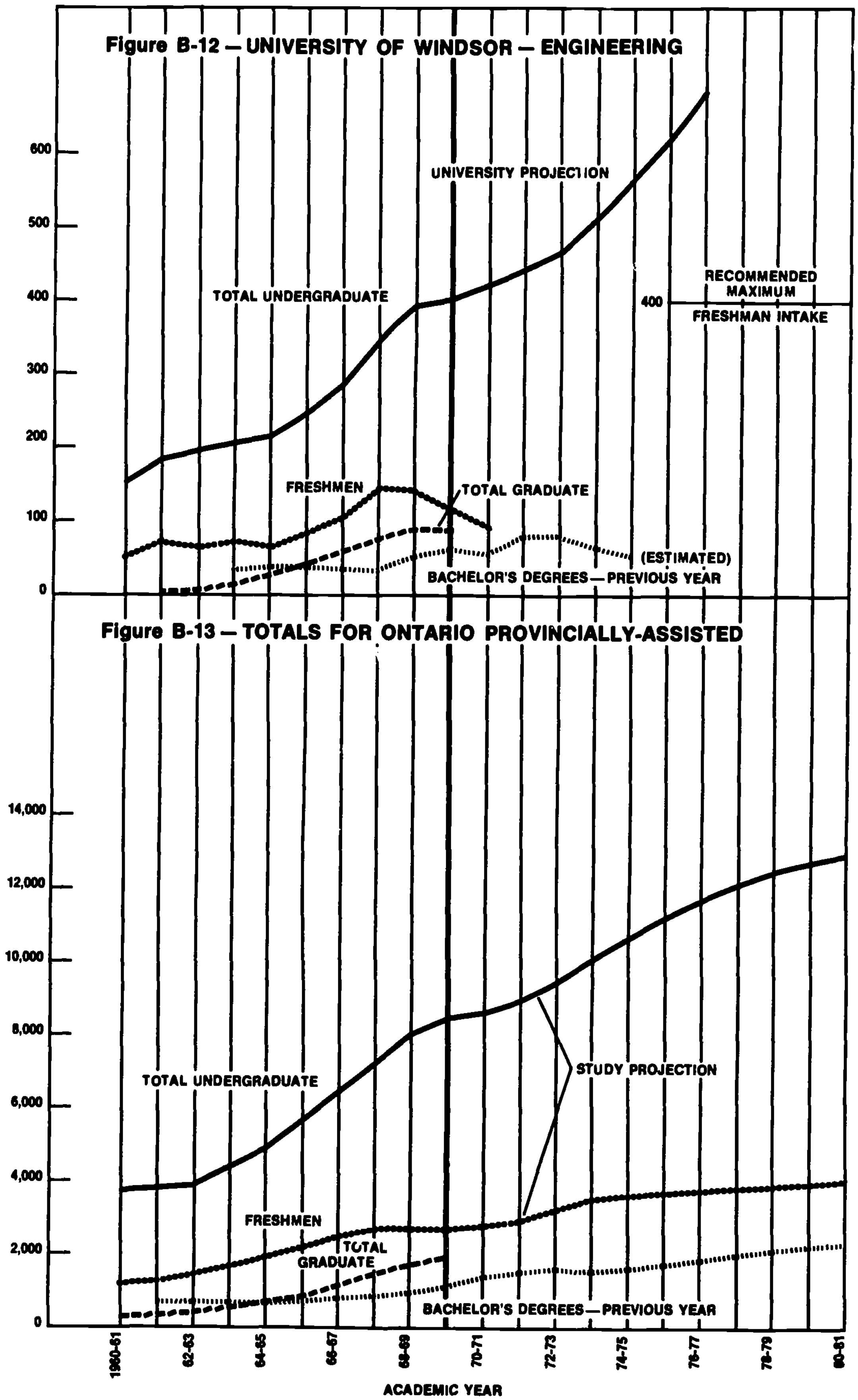

Figure B-12 — UNIVERSITY OF WINDSOR — ENGINEERING
600
500
400
300
200
100
0
UNIVERSITY PROJECTION
TOTAL UNDERGRADUATE
RECOMMENDED MAXIMUM FRESHMAN INTAKE
400
FRESHMEN
TOTAL GRADUATE
(ESTIMATED)
BACHELOR'S DEGREES — PREVIOUS YEAR
Figure B-13 — TOTALS FOR ONTARIO PROVINCIALLY-ASSISTED
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
TOTAL UNDERGRADUATE
STUDY PROJECTION
FRESHMEN
TOTAL GRADUATE
BACHELOR'S DEGREES — PREVIOUS YEAR
1960-61
62-63
64-65
66-67
68-69
70-71
72-73
74-75
76-77
78-79
80-81
ACADEMIC YEAR

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APPENDIX C

SOME COMMENTS ON TELEVISION-LINKED CLASSROOMS

The continuing education of employed engineers is part of the concern of all engineering educators. In the past, this need has been met by late afternoon or evening courses presented on campuses in the metropolitan universities and attended by full-time and part-time students. Such a practice has inherent disadvantages — the disruption of daytime lecture schedules for full-time students and the commuting and parking problems facing part-time students. Attendance by employed engineers at regularly-scheduled daytime lectures is difficult for the off-campus students, involving travel time and the general disruption of their working day. The presentation of a broad graduate program at several widely dispersed sites presents even greater difficulties. The University of Florida exemplifies this latter situation. While the main campus is at Gainesville, there was a need to provide programs at three distant and smaller satellite campuses in centres of concentrated technological activity — Daytona Beach, Orlando and Cape Kennedy. The solution, developed by Thomas L. Martin, the then Dean of Engineering, was a television network linking the four campuses with a one-way video and two-way audio system. The system is named Genesys (University of Florida Graduate *EN*gineering *E*ducational *SYS*tem) and a full description may be found in Nos. 1, 2 and 3 of the bibliography at the end of this appendix.

A general description of Genesys is provided in the report of a conference of the American Society of Engineering Education (No. 4 of the bibliography). It provides cost data, although the authors point out that these are actual costs which certainly would be lower for future installations in the light of experience with the system. They cover the expenses involved in building and equipping studio-classrooms (7,500 sq. ft. at Daytona, 7,500 sq. ft. at Orlando, 23,000 sq. ft. at Port Canaveral). Land values are included in the cost (a total of 60 acres at $2,500 per acre). It is emphasized that the amortization and the maintenance of physical plant account for more than two-thirds of the fixed portion of the annual cost of running the system. The balance, $110,000 annually, is TV line rental from Southern Bell Telephone and Telegraph Company. The fixed costs for Genesys at Florida are shown in Table C-1.

Table C-1
ANNUAL FIXED COSTS FOR GENESYS SYSTEM[a]

TV and phone line rental	$110,000
Maintenance of physical plant[b]	$110,000
Amortization of physical plant[b]	$100,000
TOTAL	$320,000
Per course (based on 196 courses a year)	$ 1,640

a The system operates on a triangular network, with cable lengths of 80, 50 and 50 miles per side.
b Includes buildings, land, furnishings and all TV equipment and supporting facilities.

Variable costs include the salaries and supporting costs of ten resident professors, eight adjunct professors and a proportion of the salaries of professors involved in the program on a part-time basis. Also included are technical and clerical costs, based upon the presentation of 196 "courses" per year. Many of the "courses" are very short — indeed the unit course involves an average of only 45 student hours.

Table C-2
VARIABLE COSTS OF GENESYS SYSTEM

	Cost	Courses (per year)
10 GENESYS resident professors	$180,000	76
8 GENESYS adjunct professors	32,000	32
Main campus professors (part-time)	110,000	88
TOTAL	$392,000	196

Variable cost per course $2,000

Table C-3 shows the summary of the total costs of the Florida System. Average course population is assumed to be 15 students, with 3 student hours per course unit.

Table C-3
TOTAL COST OF THE GENESYS SYSTEM

Type of Cost	Annual	Per "Course"	Per Student Hour
Fixed Cost	$320,000	$1,640	$37
Variable Cost	$392,000	$2,000	$44
	$712,000	$3,640	$81

It is recognized that these figures represent one particular situation and are provided here to give a gross estimate of the costs attributed to the use of a one-way video, two-way audio system.

A commercial enterprise has developed out of this Florida experience: GENESYS Systems, Incorporated, 1479 Plymouth Street, Mountain View, California 94040. Over the past three years, this company has contracted with Stanford University, University of Southern California, Rensselaer Polytechnic Institute, Union College, University of Illinois, University of Pennsylvania, Drexel University and University of Minnesota. The only system observed by members of the study group was that at Stanford University, where it was used with satellite lecture rooms in aerospace industries in the vicinity. A description can be found in No. 6 of the bibliography.

Two-way video is regarded as being prohibitively expensive, but the pedagogical importance of the talk-back feature seems to be well established. The largest single item of operating cost is the leasing of dedicated cable on which the talk back feature adds about 15% to the rental charge.

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4. Paul D. Arthur and R. S. Leavenworth, "Project GENESYS Short Courses", presented by Paul D. Arthur at the Second Annual Meeting of the Continuing Engineering Studies Division of the American Society for Engineering Education, New Orleans, La., November 1967.
5. M. E. Forsman, "Graduate Engineering Education via Television", presented at the International Convention of the Institute of Electrical and Electronic Engineers, New York, March 1968.
6. "University Instructional TV Networks – What They Mean to Industry", Wescon Technical Papers, Session 10. A collection of papers presented at the Western Electronic Show and Convention, August 1969.
   Reprints available: Region 6 (Los Angeles and San Francisco Section) of the Institute of Electrical and Electronic Engineers.
7. A. J. Morris and D. J. Grace, "Conceptual Design of a Television System for Continuing Education", IEEE Transactions on Education, Vol. E-11, No. 3 (September 1968), pp. 165-70.

APPENDIX D

SPECIAL RESEARCH FACILITIES

It seems worthwhile to list special major research facilities which have been installed in the engineering schools. A complete inventory would be a formidable and probably not very useful task, but a list of "special" facilities does involve subjective decisions. However, this risk is accepted. The result is the following list.

Carleton University

1. Closed-circuit low-turbulence wind tunnel — working section 20 inches by 30 inches, speeds up to 300 ft. per second.
2. Solid state device fabrication laboratory — class 100 laminar flow clean room with diffusion furnaces, vacuum deposition equipment and facilities for characterization and testing.
3. Electron beam systems: a 1.8 kilowatt, 130 kilovolt system and a 48 kilowatt, 70 kilovolt system. Included are a 7 cubic metre vacuum faculty, x and y beam scanning capability and in-vacuum tooling.

University of Guelph

1. Elora Research Station — a major facility made available by the Ontario Department of Agriculture and Food, for agricultural engineering research.

McMaster University

1. Nuclear Reactor: A swimming pool nuclear reactor, powered by enriched uranium fuel, with 5 megawatt power capacity. 6 neutron beam-port tubes, hot cell with 5000-curie gamma source, and a high-intensity gamma room. Peak flux is $3x\ 10^{13}$ neutrons/cm^2 (sec).
2. Model FN Tandem van der Graaff Accelerator: Maximum terminal energy 8 Megavolts, capable of accelerating light and heavy positive ions. 7 different beam port facilities.
3. Applied Dynamics Laboratory: Major structural testing facility for testing of structures up to 35 feet high. Large assortment of constant — and pulsed — loading equipment.
4. Materials Research Institute: Fully equipped laboratories for research on solid materials. Includes helium liquefier, activation analysis laboratory, two electron microscopes and two-channel electron probe microanalyzer.
5. 220 MHz Nuclear Magnetic Resonance Spectrometer: shared with University of Toronto. Located at Ontario Research Foundation, Sheridan Park.

Queen's University

1. Coastal engineering laboratory: a 20,000 square foot laboratory, housing wave tanks, sedimentation flumes, water tunnels and a model harbour basin.
2. Cold Room: 1,000 square feet for testing purposes. Will maintain temperatures of −20°F.
3. Mineral Engineering Laboratories: Full range of equipment for mineral processing.

University of Toronto

1. Structures Testing Laboratory: Full complement of high capacity test equipment for the static and dynamic testing of structures. Includes high pressure triaxial testing apparatus (1500 psi). 1200 Kip testing machine and a range of cyclic loading equipment.
2. Computer Research Facility: A separate computer system, concentrating on real time, hybrid and special computing equipment. Includes IBM 360 Model 4, Applied Dynamics AD/4 analogue, IBM 2250 video display, Calcomp plotter and two remote analogue and digital terminals for interfacing with the IBM 360/44.
3. Corona Research Laboratory: AC and DC test facilities up to 300 and 260 kilovolts respectively for the study of corona discharge phenomena. Instrumentation available for pulse waveform display, measurement of radio noise and of corona losses.
4. Radio Telescope: a 60-foot radio telescope located at the NRC National Radio Astronomy Laboratory in Algonquin Park.
5. Human Factors Laboratory: Equipped to study the information processing capability of human sensory and perceptual systems.
6. Towing Channel: 200 ft. x 5 ft. x 5 ft., with precision carriage and dynamometer.
7. Biomedical Electronics Laboratories: A group of five laboratories for studies in the application of electronics to medicinal problems.
8. Institute for Aerospace Studies: An elaborate facility at Downsview for aerospace research.

Equipment includes low-density plasma tunnels, hypervelocity launcher, magneto gas dynamic power generator, anechoic chamber, a space simulator, high-power, tunable pulsed lasers, and a flight simulator.

University of Waterloo

1. Environmental Health Laboratory: equipment includes Warburg respirometer, refrigerated centrifuge, and controlled environment rooms.
2. Power Engineering Research Laboratory: equipped with an analogue simulator for studying high voltage D.C. transmission problems, high voltage A.C. and D.C. test equipment for voltages to 500 kilovolts.
3. Manufacturing Sciences Laboratory: equipped with horizontal milling machine, Havlik plastic injection machine, Blohm grinder, VDF production lathe.
4. Experimental Chimneys and Atmosphere Diffusion Range.
5. Combustion Laboratory: includes 3 test cells, 6 atmospheric test bays and open fire test area.

University of Western Ontario

1. Boundary Layer Wind Tunnel Laboratory: Open return wind tunnel with a working section 100 ft. x 8 ft. x (5½ to 7½ ft.) high. Fan is 40 H.P. (8 ft. diameter), variable pitch. Maximum air speed: 60 ft. per second.
2. Thermophysical Laboratory: special capability of extremely precise measurement of enthalpy differences, and other themophysical properties.
3. Electrostatics Laboratory: equipped to study electrification in high vacuum, charging of aerosols, electrostatic precipitation and beneficiation of minerals by electrostatics.
4. Biochemical Process Laboratory: four fermentation reactors (largest 100 litres), with ancillary equipment for control and recording of pH, gas and energy transfer, temperature and mixing intensity.

RESEARCH INSTITUTES

UNIVERSITY	INSTITUTE	DATE STARTED	SIZE AND RESOURCES	MODE OF OPERATION
Carleton	Electronics and Communications	Planning Stage	A proposed institute concerned with the related areas of electronics and communications. A joint endeavour with Queen's University, industry, and government.	N/A
	Transportation Institute	Planning Stage	A proposed institute, originating in the Faculty of Engineering. As it develops it will become interdisciplinary; will relate to the federal transportation agencies.	N/A
Guelph	Centre for Resources Development		Involves Departments of Geography, Economics, Agricultural Economics, Soil Science and Zoology, and Schools of Landscape Architecture and Engineering.	Interdisciplinary research group, using individual grants as financial source.
	Interdisciplinary Committee on Hydrology		Involves School of Landscape Architecture, Agricultural Engineering and Soil Science.	
	Food Research Institute	Planning Stage	To involve Department of Agricultural Engineering, Food Science, Microbiology, Horticultural Science, Agricultural Economics, Nutrition, Animal Science.	Interdisciplinary Institute, funded by Department of Industry, Trade and Commerce.

UNIVERSITY	INSTITUTE	DATE STARTED	SIZE AND RESOURCES	MODE OF OPERATION
McMaster	Institute for Materials Research	1967	Involves 40 faculty members (10 from Engineering), part-time; 115 graduate students (10 from engineering); 30 post-doctorate fellows (7 from engineering) 25,000 sq. ft. of laboratory and office space. Equipment includes helium liquefier, electron probe microanalyzer, metallographic equipment, crystal growth equipment.	Financed by NRC-negotiated development grant ($500,000). Operated as an institute with a director who is a faculty member.
	Centre for Applied Research and Engineering Design (CARED)	1967	Operated on federal and university support: $50,000 per year from Department of Industry, Trade and Commerce, and $25,000 per year from McMaster University. Interdisciplinary contract research institute, 10 full-time staff (2 engineers); 24 engineers as project consultants. 1970 income about $275,000. Has own office staff and facilities; laboratory facilities leased from University.	Operated as an Industrial Research Institute. Incorporated in 1970 as university-owned and -operated company. Executes projects on contract for industry and government; faculty members as consultants.
	Applied Dynamics Laboratory	1968	An interdisciplinary dynamic laboratory, financed on capital development program, as teaching and research facility. Full-time manager (professional engineer), 4 technicians, 25 graduate students, 3 post-doctorate fellows, 9 faculty members (part-time). Structural test bay, universal testing machines MTS dynamic loading unit (20,000 pounds force).	Operated as interdisciplinary facility, through Users' Committee. Operating finances through research grants and CARED income.
	Canadian Institute for Metal-working	1970	Funded by a $600,000 grant (5 years) from Department of Industry, Trade and Commerce. Ultimate full-time staff about 10 (3 graduate engineers). Will operate on an inventory of leased machine tools (value about $250,000), with full access to McMaster shops, and reciprocal agreement with Mohawk College.	Self-contained entity, operated through CARED. Advisory board develops policy, executed by manager and staff. Aims: (1) national information centre on metal-working; (2) presentation of courses to operators and management; (3) development of metal-working production methods and cutting techniques.

UNIVERSITY	INSTITUTE	DATE STARTED	SIZE AND RESOURCES	MODE OF OPERATION
Ottawa	Institute for Northern Development	Planning Stage	N/A	N/A
	Water Resources Centre	Planning Stage	N/A	N/A
	Centre for Study on Communications and Computers	Planning Stage	N/A	N/A
Queen's	Centre for Metals and Mineral Technology	1968	Research expenditures of $300,000 per year financed by grants from Cominco, AECL, Esso Research and Engineering, International Nickel of Canada, NRC, DRB. 11 faculty members, 25 graduate students, 5 post-doctorate fellows, 10 technical assistants. Laboratory and office facilities in departments of Metallurgical Engineering, Physics, and Chemical Engineering.	Interdisciplinary research group, funded by federal government and industry. Primary aim — better integration of industry and university interests and activities.
	Canadian Institute of Guided Ground Transport	1970	Financed by grant of $100,000 per year from each of Canadian National Railways, Canadian Pacific Railway and Canadian Transport Commission, with additional support in kind from Queen's University. Research will be performed by university faculty at Queen's or elsewhere, on the basis of submitted proposals. Proposed future space allocation of 10,000-20,000 square feet; at present use existing laboratory facilities. Has own administrative personnel.	Director appointed by Principal of Queen's, may be a member of faculty. Currently run by acting directors: H. G. Conn until October 1970, Clifford Curtis after October 1970.
	Institute for Studies in Communications	Planning Stage	N/A	N/A

UNIVERSITY	INSTITUTE	DATE STARTED	SIZE AND RESOURCES	MODE OF OPERATION
Toronto	Institute for Aerospace Studies	1949	Started by a DRB grant in 1949, is now supported by 13 funding agencies in Canada and the U.S.A. to the extent of $666,000 annually. Staffed by 15 full-time professors, with a total of 83 graduate students in 1969. New Building on 18-acre site provided by U. of T., constructed in 1959 (DRB financed). Extensions to building in 1961-63 with funds of U. of T. and Ford Foundation. Large supersonic wind tunnel, shock tubes, rocket research laboratory, low-speed wind tunnel, anechoic chamber, hypervelocity laboratory, structural mechanics laboratory. Operating budget, 1969-70, $458,000.	A separate graduate division of the Faculty of Engineering, with a director who is a member of faculty. Responsible for entire research program and undergraduate teaching in the aerospace sciences.
	Institute of Biomedical Electronics	1962	A full-time staff, 8 supporting staff, 20 part-time staff, 30 students (graduate and undergraduate). 10,000 sq. ft. of laboratories and offices.	Operates research program common to medicine and engineering. Provides education in physical sciences for medical personnel, and in life sciences for engineers.
Waterloo	Industrial Research Institute	1967	Operated on $48,000 per year from Department of Industry, Trade and Commerce, and services and facilities supplied by the university. Interdisciplinary contract research institute, 5 full-time staff (2 professionals, 3 secretaries); 1970 income about $300,000.	Operated as an Industrial Research Institute. Laboratory facilities paid for by overhead charges and direct assessment on contract. Faculty members as consultants and principal investigators.
Western Ontario	Centre for Radio Sciences	1968	12 members (2 engineers), 14 associate members (1 engineer). Has one permanent building at the Delaware Radio Observatory.	Interdisciplinary research group to execute research in radio science. Projects are individually supported and are related to the national space program.
	Centre for Air Pollution Studies	Planning Stage	N/A	Has the objective of coordinating teaching and research relative to control of air pollution and establishment of air quality criteria, and of offering courses to industry and government.

UNIVERSITY	INSTITUTE	DATE STARTED	SIZE AND RESOURCES	MODE OF OPERATION
Western Ontario *Cont.*	Institute for Industrial Cooperation	Planning Stage	N/A	A proposed Industrial Research Institute with support from the Department of Industry, Trade and Commerce, to perform industrial research on contract.
	Centre for studies in Technology, Innovation and Human Affairs	Planning Stage	N/A	Would sponsor educational and research programs on Canadian science policy — goals and priorities.
Windsor	Industrial Research Institute	1967	Supported by an annual grant from Department of Industry, Trade and Commerce, of $35,000. 22 faculty members involved in industrial projects as consultants; projects also involve graduate students and technical staff. Laboratory services leased from University. Salaried manager, administrative assistant and office personnel.	Incorporated in 1967 as limited liability company owned by the University. Board of Directors: university, industry, government represented. President: Dean of Applied Science.

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APPENDIX E

ESTIMATED EQUIPMENT INVENTORIES[a] — FACULTIES OF ENGINEERING

Value of Equipment (thousands of dollars)

University	Teaching Function	Both Teaching and Research	Research Only	Total
Carleton	256	665	126	1,047
Guelph	142	190	142	474
Lakehead		650	25	675
McMaster	724	1,264	767	2,755
Ottawa	660	280	500	1,440
Queen's	975	1,340	2,089	4,404
Toronto	3,156	2,332	5,738	11,226
Waterloo	1,031	2,346	733	4,110
Western	960	640	640	2,240
Windsor	847	401	635	1,883
	8,751	10,108	11,395	30,254

a Equipment only — does not include buildings or furnishings.

Figure F-1 — DEGREES HELD BY ONTARIO ENGINEERING TEACHERS — BY UNIVERSITY 1969-70

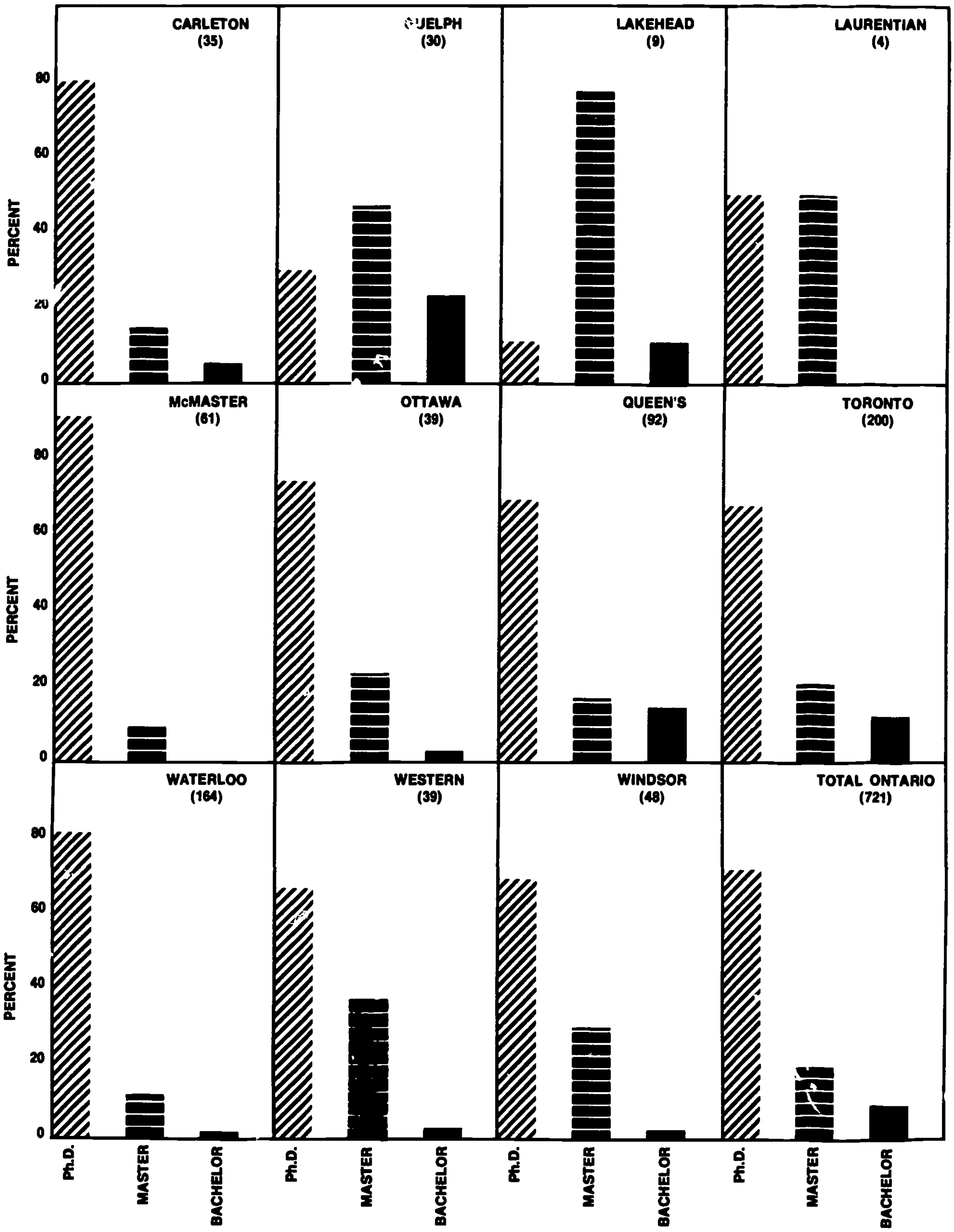

Figure F-2 — DEGREES HELD BY ONTARIO ENGINEERING TEACHERS — BY DISCIPLINE 1969-70

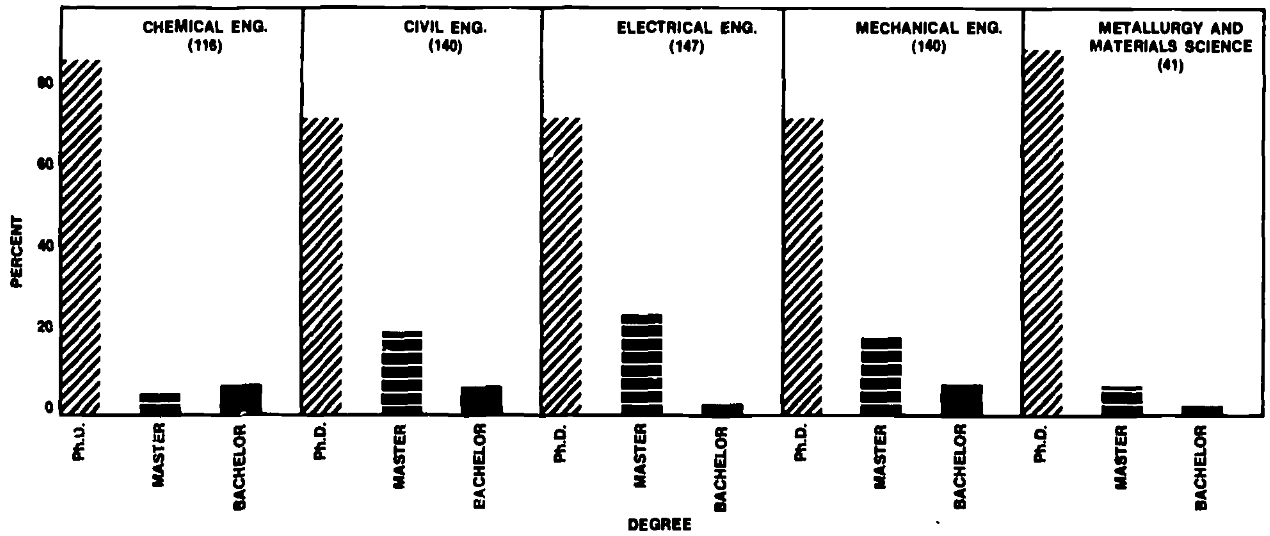

Figure F-4 — AGE DISTRIBUTION OF ONTARIO ENGINEERING TEACHERS — BY DISCIPLINE 1969-70

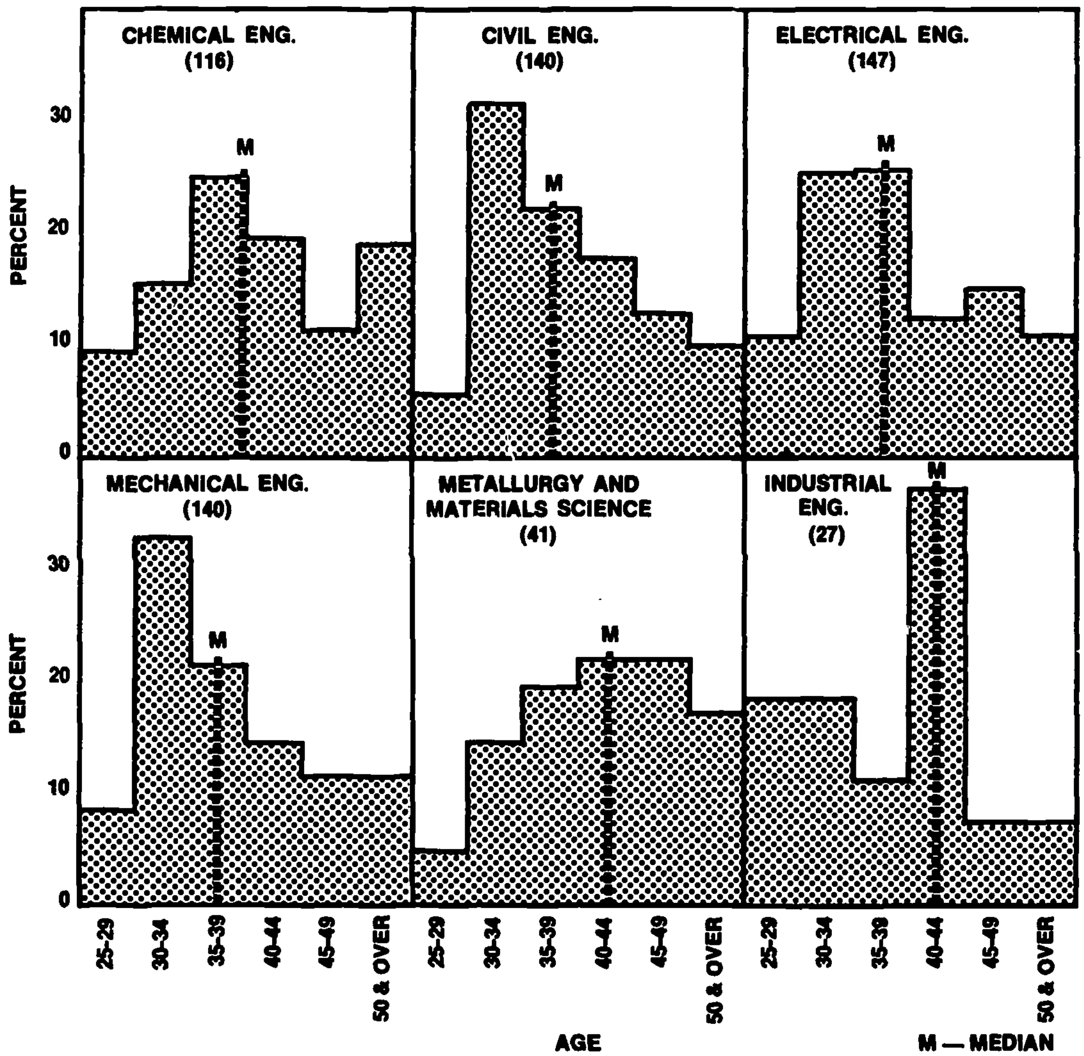

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Figure F-3 — AGE DISTRIBUTION OF ONTARIO ENGINEERING TEACHERS — BY UNIVERSITY 1969-70

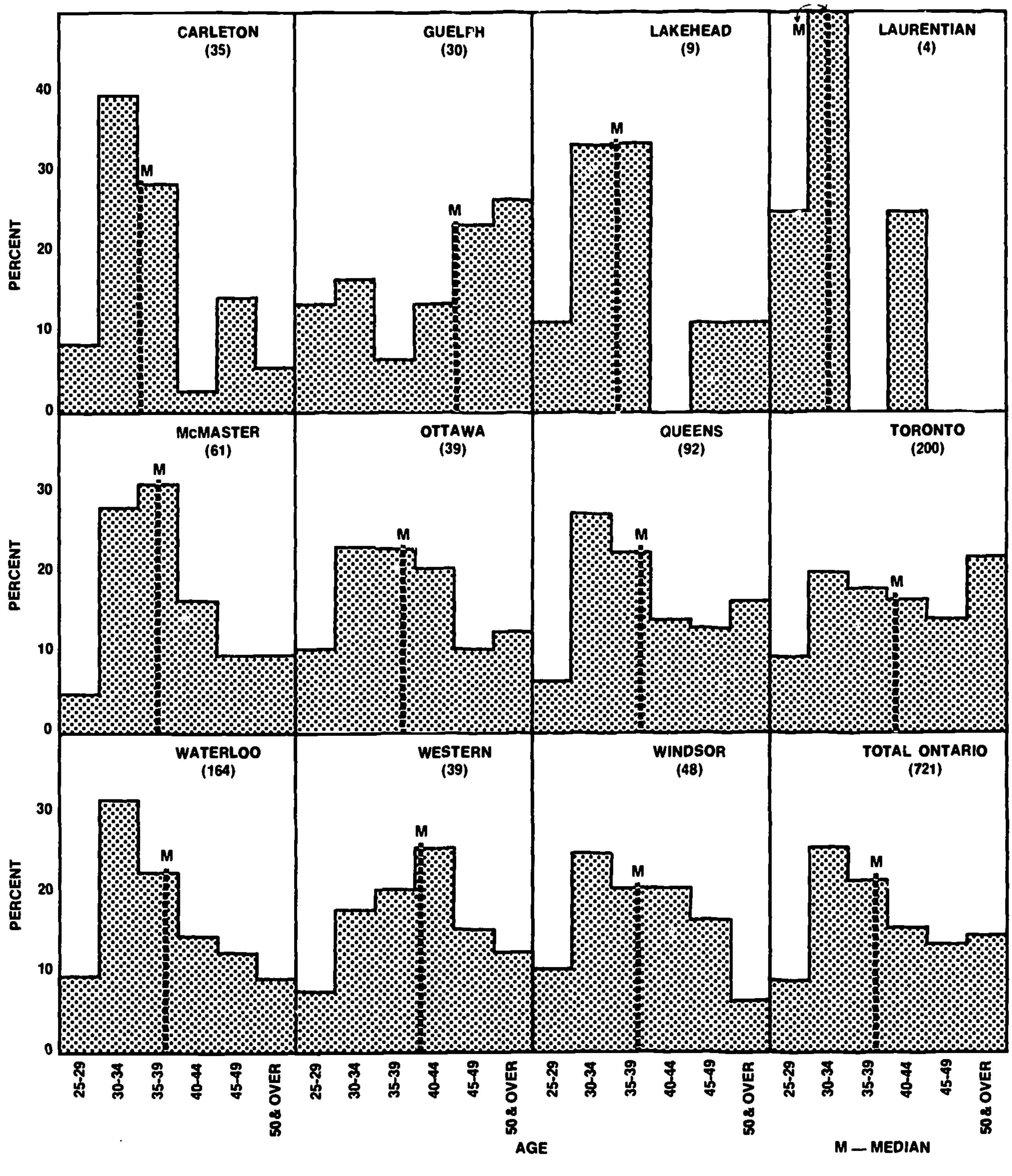

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Figure F-5 — BIRTHPLACE OF ONTARIO ENGINEERING TEACHERS — BY UNIVERSITY 1969-70

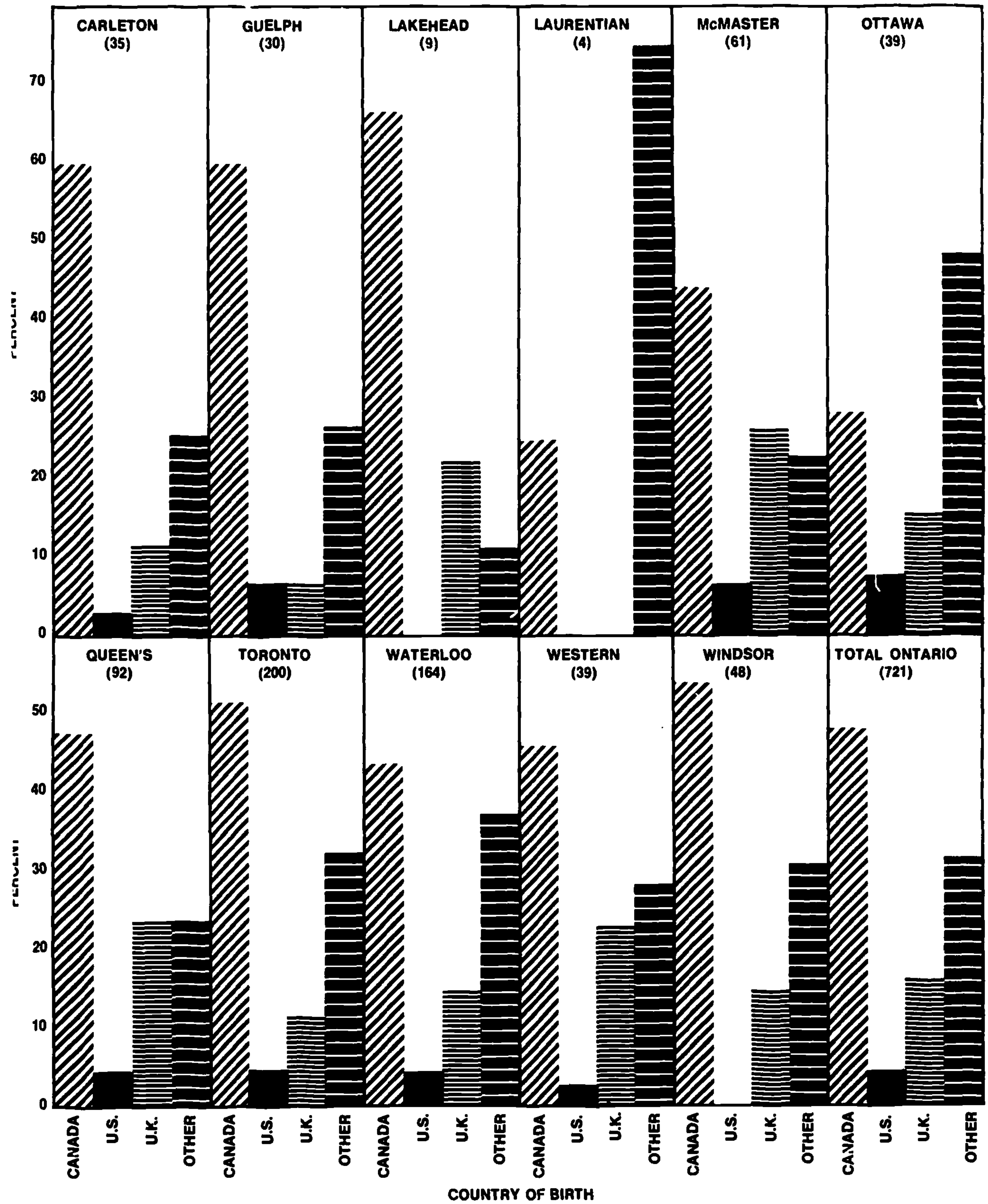

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Figure F-6 — BIRTHPLACE OF ONTARIO ENGINEERING TEACHERS — BY DISCIPLINE 1969-70

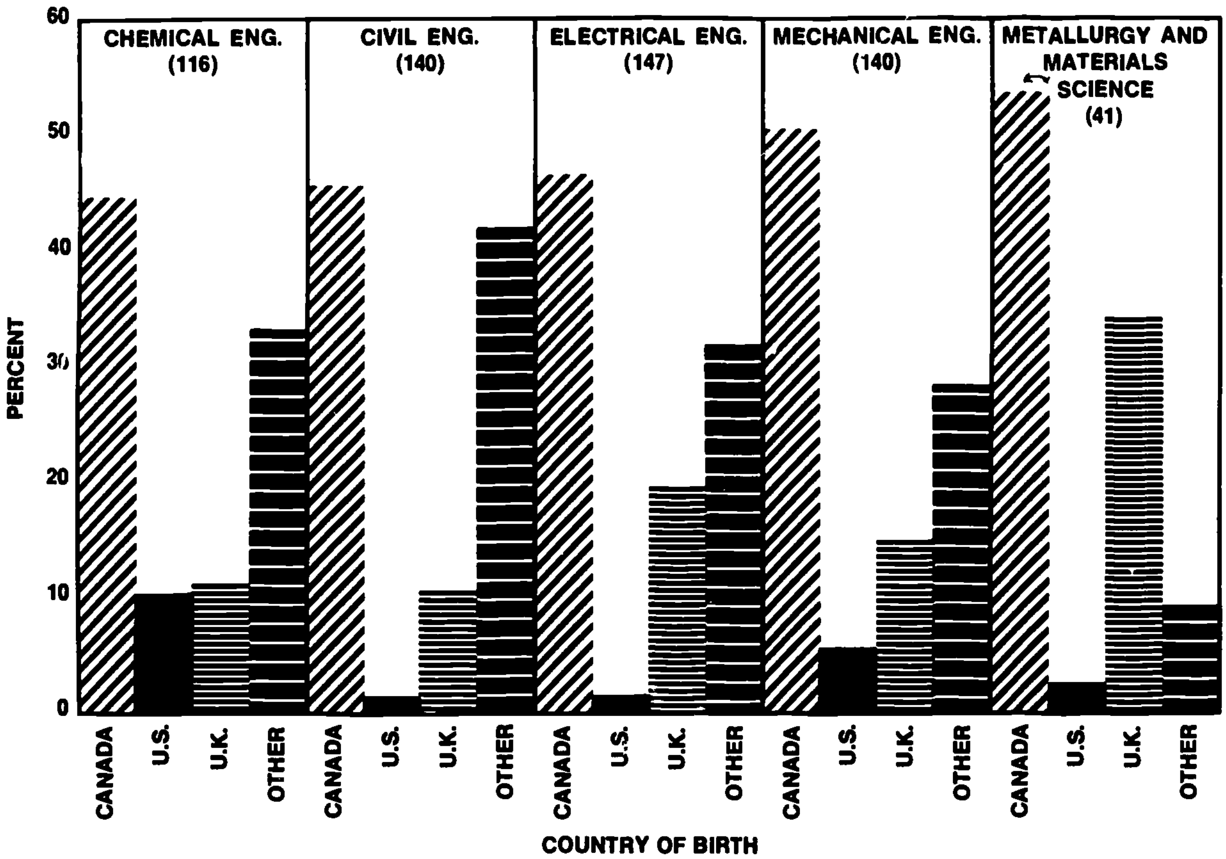

Figure F-8 — UNIVERSITY OF LAST DEGREE OF ONTARIO ENGINEERING TEACHERS — BY DISCIPLINE 1969-70

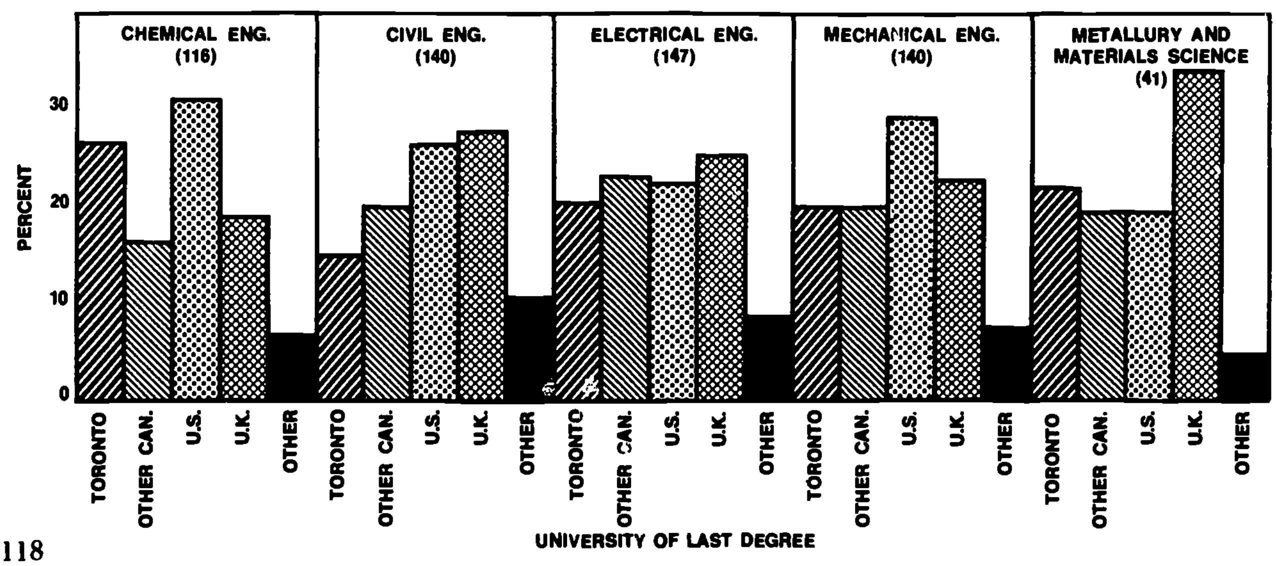

Figure F-7 — UNIVERSITY OF LAST DEGREE OF ONTARIO ENGINEERING TEACHERS — BY UNIVERSITY 1969-70

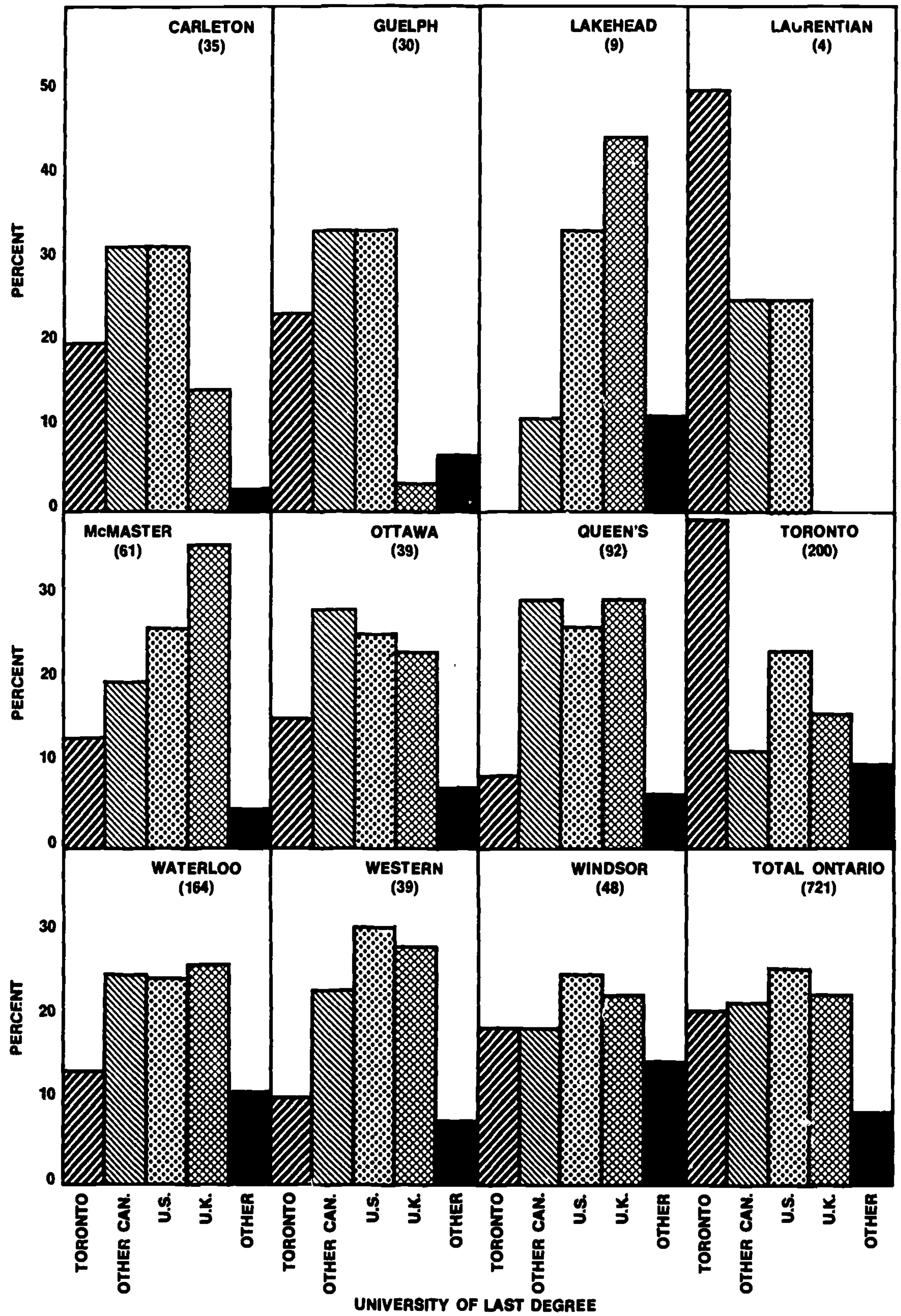

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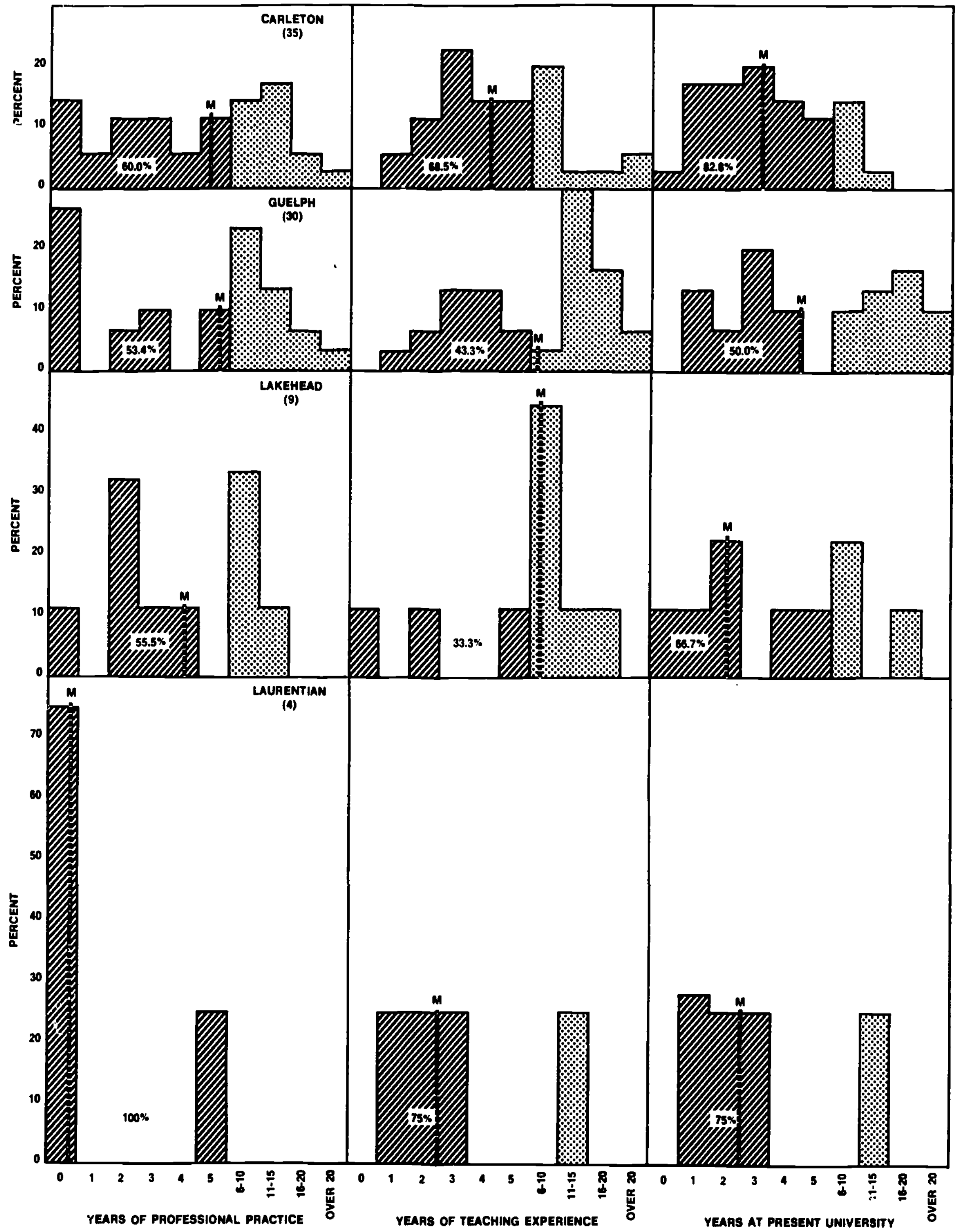
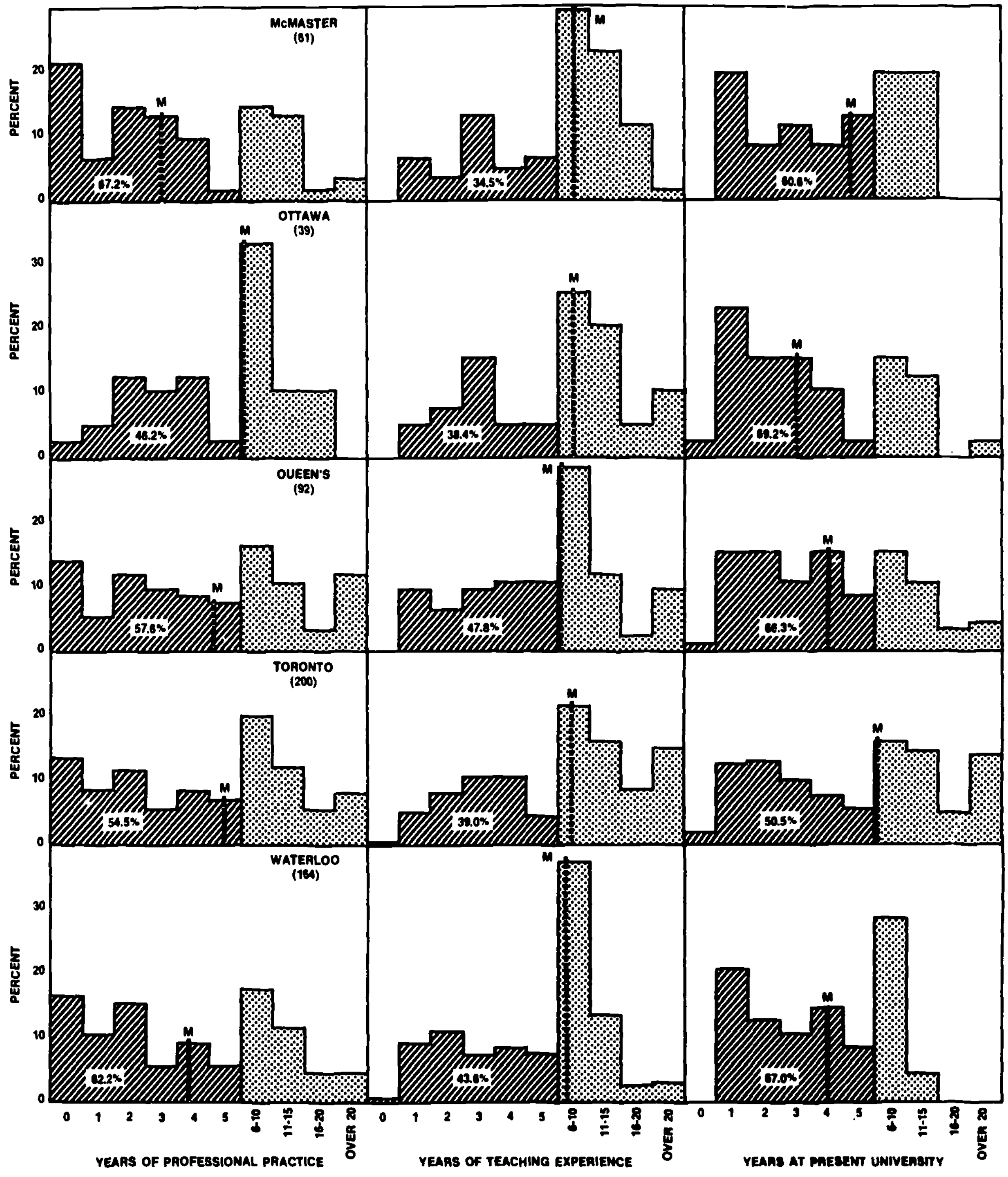
Figure F-9, Part 1 — EXPERIENCE OF ONTARIO ENGINEERING TEACHERS — BY UNIVERSITY 1969-70



NOTE: FIGURES IN SHADED PORTION ON LEFT REPRESENT PERCENTAGE IN 0-5 YEAR RANGE M — MEDIAN

Figure F-9, Part 2 — EXPERIENCE OF ONTARIO ENGINEERING TEACHERS — BY UNIVERSITY 1969-70



NOTE: FIGURES IN SHADED PORTION ON LEFT REPRESENT PERCENTAGE IN 0-5 YEAR RANGE M — MEDIAN

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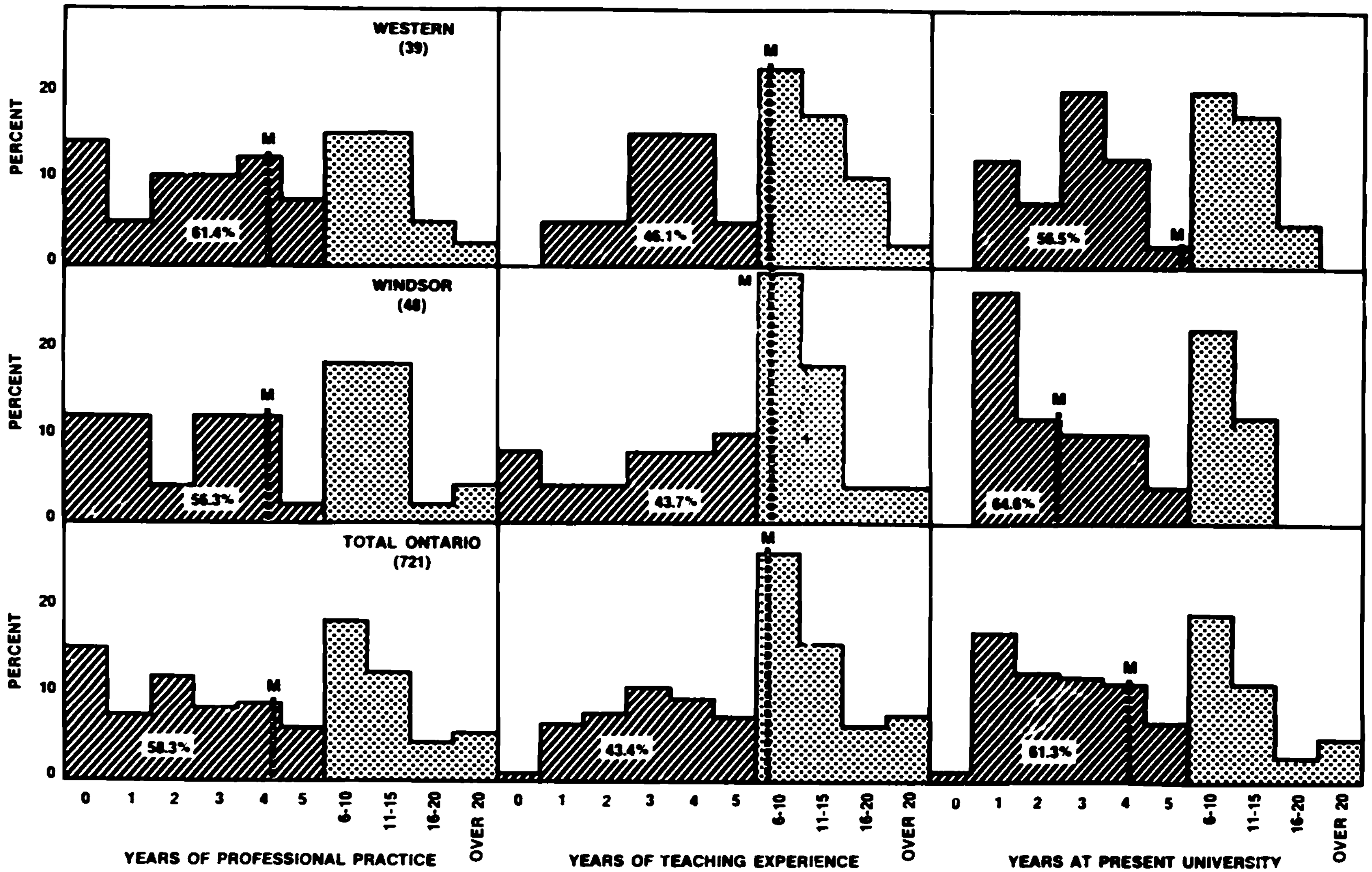
Figure F-9, Part 3 — EXPERIENCE OF ONTARIO ENGINEERING TEACHERS — BY UNIVERSITY 1969-70



NOTE: FIGURES IN SHADED PORTION ON LEFT REPRESENT PERCENTAGE IN 0-5 YEAR RANGE M — MEDIAN

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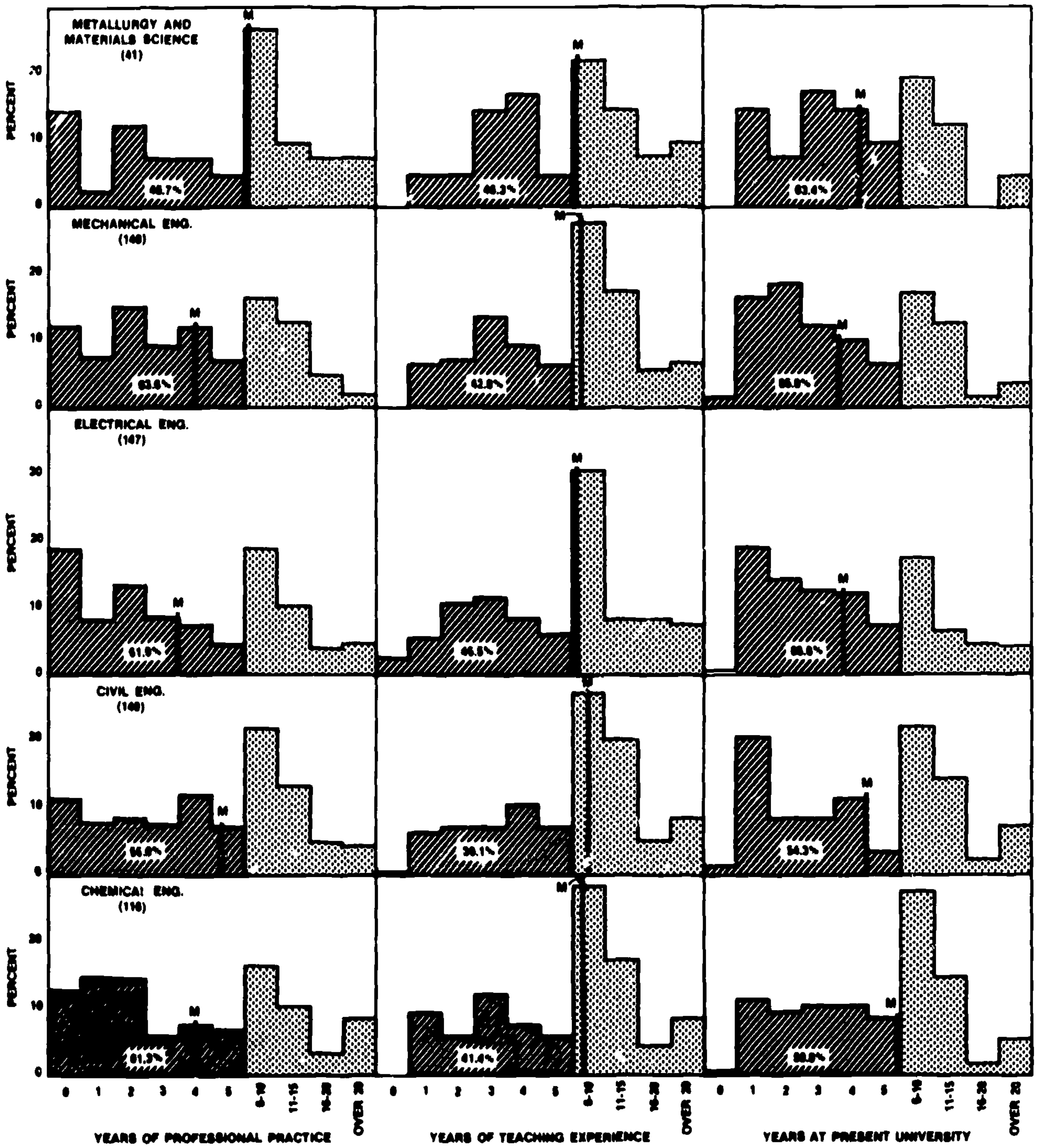
Figure F-9, Part 4 — EXPERIENCE OF ONTARIO ENGINEERING TEACHERS — BY DISCIPLINE 1969-70



NOTE: FIGURES IN SHADED PORTION ON LEFT REPRESENT PERCENTAGE IN 0-5 YEAR RANGE M — MEDIAN

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APPENDIX G

PLACEMENT EXPERIENCE

One of the better yardsticks for measuring the demand for engineers is the intensity of recruitment activity at the universities. There is a placement service on each campus which is responsible for organizing student interviews with potential employers, and so the following was asked in the questionnaire sent to the Ontario faculties of engineering (Appendix I, question 6c):

> "Please provide any recent reports or statistics on student placement services for engineers in your university. Include any remarks you would care to make concerning the placement of graduate students, particulary Ph.D.'s."

Unfortunately, the request was not sufficiently specific and this resulted in a variety of responses. Consequently, it has not been possible to compress the data into tabular form. However, the answers did provide some interesting information and we have reproduced comments taken from the submission of each university.

CARLETON UNIVERSITY

It provided information covering the years 1966-67 and 1967-68 which lists the number of interviews arranged for engineering students, the B.Eng. graduates, and their place of employment on graduation. These data can be summarized as follows:

For 1966-67, 39 companies held 201 interviews with 37 baccalaureate graduates, 30 of whom accepted offers of employment. In 1967-68, 40 companies held 291 interviews with 43 students, 27 of whom were employed following graduation.

UNIVERSITY OF GUELPH

No statistical data are available on the placement services provided for its engineers. The small number of graduate students have posed no problems, with the exception of those from Asia. There has been an indication that more graduate students with a professional orientation could be placed in the processing and service industries associated with agriculture.

McMASTER UNIVERSITY

The Canada Manpower Centre, in conjunction with the University, makes available a Student Placement Office on campus. Graduating engineering students have not encountered problems in gaining suitable employment before the date of their graduation. However, some foreign students encounter placement difficulties and may remain unemployed for several months after graduation.

A survey of their Ph.D. graduates shows them to be employed as follows:

University teaching in Canada	1
University teaching in U.S.A.	2
Employed by industry in Canada	8
Employed by industry in U.S.A.	10
Government service in Canada	2
Government service in Pakistan	1
Post-doctoral Fellowship in Great Britain	1

UNIVERSITY OF OTTAWA

Undergraduate students arrange interviews with prospective employers through the Student Placement Service. Graduate students may avail themselves of these facilities but some seek employment independently. Ph.D. students here have encountered difficulties recently in securing positions to their particular liking and interest.

QUEEN'S UNIVERSITY

As far as undergraduate employment is concerned at least 90% of the Applied Science students registered in September 1969 had been able to secure employment during the previous summer.

Table G-1

UNDERGRADUATE EMPLOYMENT — QUEEN'S

Year	% of summer employment	% of jobs held relevant to their Applied Science courses
1	87.1	54.5
2	91.2	63.6
3	91.0	74.9
4	90.9	89.2

We are not aware of any serious difficulty in placing engineering Ph.D. graduates. In recent years, with few exceptions, the demand for graduate engineers has exceeded the supply, although this year there has been a drop in the number of offers per student.

UNIVERSITY OF TORONTO

In the early months of the 1968-69 academic year, some concern was expressed by placement officers and recruiters over the lessening in demand for university graduates that appeared to face the class of 1969. There were expressions of gloom in regard to Canada's economic situation, interest rates on expansion capital were high, and a general mood of belt-tightening prevailed in both the public and private sectors. A good number of government and industrial recruiters were actively considering a temporary halt to campus recruiting. Employers who did arrange visits scaled down their estimates of requirements for graduates. All these factors seemed to pertain to the situation in the labour market at the end of 1968. A large number of community college graduates would be available, and moreover many employers began to embark on serious efforts to achieve better utilization of present staff before taking on any additional personnel. Undoubtedly, this policy has had some short-term adverse effects on the demand for university graduates, but in the long run it should enhance their position within the organization and also ensure that jobs offered to them will be more fully compatible with their abilities and education.

Early in 1969, there was a renewed demand for graduates, particularly at the bachelor's level. Employers who had been on campus again approached the Placement Centre to advertise additional vacancies, while those who had done no recruiting now indicated a wish to do so. The net result was a deluge of vacancies in a wide range of disciplines. In February, March and April, a significant number of graduates found suitable starting positions, either by individual referral from the Placement Centre or through supplementary on-campus interviews.

The Toronto Placement Centre has a full-time member of staff concerned with engineering students, and has encountered no difficulty in placing undergraduates, either upon graduation or during the summer. The general trend in demand for 1969 graduates in engineering and science courses was down by about 3.5%. There was an increase in demand for graduates in mechanical and electrical engineering and for students with a diploma in computer science. The pulp and paper industry has fewer opportunities for new graduates in chemical engineering, while there continues to be a shortage of geological and metallurgical graduates.

Salaries reflected the moderating demand. In those programs with large numbers of graduates, only electrical engineers received more than a 2 to 3% increase in starting rates while the average increase was 2¼%. Initial salaries for engineers entering the field of chartered accountancy were $50 to $75 lower than those for graduates accepting course-related employment.

An interesting phenomenon which seemed to be more prevalent than ever before was the number of engineering graduates who indicated that they did not intend to pursue technical careers. While most of them are prepared to serve an apprenticeship in industry as junior engineers, their aim is to move into the ranks of management as quickly as possible, not only to reap the financial rewards of such positions but also to escape from being "trapped" in an engineering job.

With respect to placing postgraduate students, the departments are playing an increasingly important role as a consequence of their interaction with industry and government. The development of consulting teams, of broad interdisciplinary programs of research and of a strong vein of entrepreneurial interest among faculty members is strengthening the prospects for this important service.

Nevertheless, the placement of Ph.D. graduates is expected to become increasingly difficult. Flexibility of outlook will be an important characteristic for the future doctoral candidate.

A study on the destination of Ph.D.'s prepared by the Toronto School of Graduate Studies in December 1969 shows that 29 out of the 31 persons to be awarded an engineering Ph.D. in 1968-69 were placed at the time of reporting.

Canadian industry	8
Industry abroad	4
Ontario colleges and universities	9
Other Canadian universities	3
Universities abroad	1
Canadian government service	2
Post-doctoral fellows in Canada and abroad	2
	29

The holders of master's and doctoral degrees appear to be facing increasing difficulty in finding suitable employment. More and more of these highly qualified people are being forced either to emigrate to the United States or to accept positions that do not fully utilize their abilities and training. There is a slackening in demand for research-minded Ph.D.'s for both government and industry as well as for university teaching appointments. At a time of tightening governmental, industrial and educational budgets, opportunities for senior students are the ones most seriously affected.

UNIVERSITY OF WATERLOO

The question in regard to placement was not answered directly in the Waterloo submission, but data were provided on the destination of engineering graduates for the years 1962 to 1968. There were 867 graduates at the bachelor's level during this period, of whom 62.2% went with companies in the cooperative program, 10.4% to other companies, 80.8% on to graduate studies and 6.6% to other destinations. Less than 1% entered industrial employment in the United States. Of the 630 bachelor graduates proceeding to industry, 85.7% were employed by companies in the cooperative program, and 58% returned to their last employer.

39 Ph.D.'s graduated between 1962 and 1968, of whom 21 took positions in a Canadian university, 4 with the federal government, and 3 in Canadian industry. Of the remaining 11, 2 entered industry in the United States, 7 took employment in another country and the destination of two is not known.

UNIVERSITY OF WESTERN ONTARIO

The University Placement Office reports the following students registered for job placement in the years 1967-68 and 1968-69:

Table G-2

PLACEMENT REGISTRATIONS — WESTERN

Year	Summer	Bachelor's	Master's	Ph.D.
1968	65	43	7	0
1969	100	58	29	1

Between 1968 and 1969 the total number of companies recruiting on campus for science and engineering students dropped from 109 to 101. However, there was no noticeable decrease in the availability of jobs for engineering students.

UNIVERSITY OF WINDSOR

The only relevant data available concerning the engineering graduates are the following:

Year	No. of graduates	No. placed through Placement Office
1697	33	21
1968	46	27
1969	58	34

The balance of graduates either obtained employment on their own initiative or went on to graduate work. A lack of statistics is due to the fact that reporting is voluntary both from the graduate and the hiring company.

In the past three years all bachelor's graduates have been placed, but now there appears to be some difficulty in finding suitable employment, and graduates at the master's and Ph.D. levels have experienced considerable difficulty in securing jobs in industry. The bulk of the post-graduates find employment either in government or in universities on post-doctoral research and teaching assignments. There is more of a market for doctoral graduates with several years in industry, but there is considerable difficulty in arranging this experience.

APPENDIX H

UNIT COSTS[1]

METHOD

The object of this part of the study was to establish the unit cost (annual cost per student) for each engineering student in the system, for the year 1969-70. Throughout this study the term "cost" has been used rather indiscriminately. In a corporate environment, the cost is what the purchaser pays, and it covers all outlays including profit. A more precise term in the university context would be "expenditure" — the amount from income spent by each university on engineering students. The word "cost" is adequate as perceived internally by each university, but viewed externally, costs should be considered as expenditures. The study covers all ordinary operating costs including engineering department and faculty budgets, and all university "overhead" accounts including library, administration and plant maintenance.

The basis for distributing costs was staff-contact hours. Unit costs were developed as the product of two factors: cost per staff-contact hour and staff-contact hours per student.

DEFINITIONS

Throughout the study the following definitions were used as guidelines:

Term —For programming purposes, a convenient division of the academic year, usually thirteen weeks in Ontario.

Class —One subject given under a single title for a single term (lecture and/or laboratory and/or tutorial).

Section —The sub-division of a class for teaching convenience.

Program —A compilation of classes and/or research and/or field work leading to a specific degree.

Staff-contact Hour —The time spent by a teacher instructing a class. Thus, a class of 100 students receiving instruction for two hours per week generates 2 staff-contact hours and 200 student-hours per week.

Engineering Faculty Administrative Unit (referred to hereafter as Engineering) — A group of resources (faculty and staff, equipment and supplies) falling within an engineering faculty budget, under the administrative control of a dean or director, often divided into departments or discipline groups.

SOURCES OF DATA

Data were extracted from the submission provided by each university (Tables 1, 2, 3 and 4, and responses to question 5). Budgetary information was provided in separate submissions by the deans of engineering and the university business officers.

STAFF-CONTACT HOURS PER STUDENT

All service teaching performed outside Engineering for programs within the faculty or school were grouped into a single classification. All teaching services provided by Engineering but not related to enginering programs (i.e. service teaching to students from other programs or non-degree students) also were considered as a separate classification. Wherever possible, within Engineering, distinctions were maintained between departments and years in a program.

The staff-contact hours for the lecture, laboratory and tutorial components of each class were computed by multiplying the annual staff-contact hours per section by the number of sections required for each component. Then they were prorated among students in each year of each program. If several departments taught different sections of the same class, the relevant staff-contact hours were assigned to each department.

The result was a "staff-contact hour matrix" for each university. Each vertical column corresponded to a department, and listed staff-contact hours for each program within Engineering, and all programs for students from other faculties. The horizontal rows contained, by year in program, the number of staff-contact hours provided by each department, or the group of outside faculties. Two matrices were prepared for each university: one for undergraduate engineering programs and one for class instruction in graduate programs. No distinction was made between different levels in the graduate sector. Therefore master's and doctoral candidates were considered

[1]A more detailed description of the cost study is given in Ivor W. Thompson and Philip A. Lapp, *A Method for Developing Unit Costs in Education Programs*, CPUO Report 70-3.

under the single term "graduates". Graduate thesis supervision time was treated separately.

COST PER STAFF-CONTACT HOUR

The first step in deriving this factor was to divide each department or faculty budget between formal instruction, represented by staff-contact hours, and informal instruction, represented by graduate supervision. Traditionally, such allocations had been made from surveys of the distribution of each faculty member's time. This proved to be unsatisfactory, and so in lieu of such an approach, a technique was adapted from the Committee of Vice-Chancellors and Principals in the United Kingdom.

Under this modified scheme, an implicit relationship was assumed between the cost of one staff-contact hour and the supervision of one graduate student (excluding formal classroom instruction). For the purposes of thesis supervision and research, each graduate student was identified with a particular department.[2] It was assumed that each graduate student required a fixed number (K) of hours of annual supervision excluding formal instruction. Thus, the total teaching load of any one department could be expressed as the sum of its total annual staff-contact hours, plus the product of the K factor and the number of graduate students supervised in that department. This sum is referred to as the number of "teaching equivalents".

To find the value of K for Ontario engineering schools, a linear regression was established between teaching equivalents and the teaching salary component of the budget for each of the thirty-seven departments involved in the study. These components were established by analyzing the response to question 5b[3] on the approximate time distribution of faculty members. It was concluded that an average of 70% of a faculty member's time is devoted to teaching and supervision, with the balance being spent on administrative duties (15%), consulting (10%) and professional and public service (5%). Therefore, 70% of academic salaries was used in the K-value determination.

The best linear regression for the thirty-seven points yielded a correlation coefficient of 0.98, and a final value of K equal to 150 staff hours per graduate student. (This corresponds to a weekly average of 3 hours per student, for a 50-week year.) This value of K was used to divide each department's total budget between formal instruction and graduate supervision in the same proportion as its contribution to the total departmental teaching equivalent. The cost per staff-contact hour was set equal to the portion of the total departmental budget devoted to formal instruction (including the department's share of faculty office costs prorated among all departments within Engineering) divided by the total staff-contact hours taught by the department to all students.

Also, it was necessary to develop the cost per staff-contact hour for classes taught by other faculties. This cost was assumed to be equal to the over-all cost per staff-contact hour for Engineering (the total instruction cost of all departments within Engineering, divided by the total number of staff-contact hours taught by these departments) multiplied by the quotient obtained by dividing the student/staff ratio for Engineering by this ratio for the whole university.

The above procedure yields a tabulation of instruction cost per staff-contact hour for each department within Engineering, and for outside faculties, in each of the universities.

COSTS PER STUDENT

The two factors developed above must be combined to yield unit costs (excluding university overhead). For undergraduate programs every element of the staff-contact hour matrix was multiplied by the appropriate departmental instruction cost per staff-contact hour. The unit costs were computed by adding the costs along each horizontal row, and dividing the result by the corresponding number of F.T.E. (full-time equivalent) students in each program and year.

The same procedure was followed for graduate programs to generate the instruction portion of unit costs, to which must be added the graduate supervision costs — that portion of the total departmental budget devoted to graduate supervision divided by the corresponding number of F.T.E. graduate students. This sum yields unit cost for each graduate program in each university (excluding research grants).

A compilation of research grants for 1969-70 (designated assisted research) was provided on a departmental basis. They were divided by the appropriate number of graduate students and added to the above cost per graduate student to yield a unit cost including assisted research. (For Engineering, this money is derived principally from the National Research Council.)

Finally, it was necessary to apply university

[2]Undergraduate programs are not associated with one particular department, because of cross-departmental teaching.

[3]See Appendix I.

overhead to arrive at total unit costs. The percentages to be applied as overhead to the academic and research cost figures developed above were derived from the UA-4 forms submitted by each university to the Department of University Affairs.

SOURCES OF ERROR

This method of computing unit costs involved certain assumptions whose validity is open to question. The most important assumption is the one used in prorating the departmental budget between instruction and graduate supervision: that each graduate student absorbs a fixed number of staff hours for annual graduate supervision. The validity of this assumption was tested by the dispersion of the final K-value regression for the thirty-seven departments in Ontario. The correlation coefficient was 0.98, and over 80% of the points fell within an 18% band about the regression line. Anomalies will occur in some departments because of the mixture of thesis and course-work master's degree students, and variations in thesis supervision practice.

A second assumption used in the K-value determination was the portion of academic salaries devoted to either instruction or graduate supervision, assumed to be 70%. The portion will vary among departments, and this figure was chosen on the basis of the submissions without a detailed time distribution study of university staff in all the universities.

These two assumptions result in a calculated percentage split of the departmental budget between instruction and graduate supervision, which was compared with the estimated value provided by some universities. In general, the calculated percentage devoted to graduate supervision was slightly higher than university estimates, the average difference being 8%.

A third assumption was the use of student/staff ratios to compute the contact hour costs for departments outside Engineering. There would appear to be few alternatives until a similar cost study is conducted for all other faculties. On the one hand, student/staff ratios are often used for cost comparisons and were readily available, but on the other hand they reflect relative costs only when policies in regard to teaching are the same throughout the entire university.

A fourth assumption was the uniform division of assisted research money among all graduate students within a department. There are specific instances where its validity may be questioned, but no reasonable alternative was apparent from available data.

The final assumption was the method used to distribute university overhead. This was added to costs derived from departmental budget data to arrive at final unit costs. It included costs of library, student services, scholarships, bursaries, administration, plant maintenance, general expenditures and net deficit on ancillary enterprises, all expressed as a percentage of the unit cost derived from academic costs and research grants. Furthermore, other errors of omission could have affected this final calculation, since some of the overhead items in the UA-4 forms often are credited to the departmental budget. Some universities did provide data on these additional costs, and these were removed from the departmental budget.

The above assumptions create possible errors in the costs per contact hour. Also errors will enter into compilation of the staff-contact hours per student, because the tabulations from Tables 1 and 2 of the submissions could contain errors and omit complete classes. If classes given by staff in Engineering were omitted, then only the distribution of costs among programs would be altered, and not the total costs for each university. For example, undergraduate thesis contact hours were not reported by all universities. Therefore it was decided to omit these hours from the undergraduate contact hour matrix, so that undergraduate thesis costs were distributed evenly over all teaching equivalents in Engineering, and hence relative fourth-year costs may have been slightly reduced.

Classes given by staff outside Engineering and omitted from the tabulation could not be included in the total, and therefore were lost. In some cases, the classes taught to graduate students by staff from other faculties were omitted, so that these final unit cost figures are low.

POLICY VARIABLES

A principal purpose of the cost study was to identify specific quantities that could be measured and then used to advantage in establishing administrative practices and policies. These quantities, or policy variables, can be derived from the unit cost computation as described above.

There are eight policy variables, and each can be controlled within a limited range. These variables combine in a direct way to yield unit cost, so that it is theoretically possible to blend them in an optimum fashion, consistent with fixed standards of quality, so as to minimize unit cost.

In the development of total unit costs, the contribution of each department to the total instruction cost of any program can be expressed as the product of two factors:

$$\begin{array}{c}\text{departmental instruction}\\ \text{cost per student}\end{array} = \begin{array}{c}\text{departmental instruction}\\ \text{cost per staff-contact hour}\end{array} \times \frac{\begin{array}{c}\text{staff-contact hours}\\ \text{devoted to the program}\\ \text{by the department}\end{array}}{\begin{array}{c}\text{number of students in}\\ \text{the program}\end{array}}$$

The cost per student for any year of a program is the sum of all such costs incurred by each department that is teaching classes in the program. The first factor on the right-hand side of the above expression is a departmental cost, and can be averaged for all departments within the faculty by weighting the cost of each in accordance with its total staff-contact hour teaching load to yield an Engineering faculty cost. The other factor is a program variable, and can be added for all departments within the faculty and all programs in any year to yield a total for all such classes taught within Engineering. The product of these two factors is the Engineering portion of unit cost for all classes in a given year. For classes taught in any year of a program by other faculties, their instruction costs are multiplied by the appropriate staff-contact hours per student, and the unit costs so derived must be added to those computed for Engineering.

INSTRUCTION COST PER STAFF-CONTACT HOUR

The departmental instruction cost per staff-contact hour is equal to the portion of the departmental budget devoted to formal instruction divided by the total number of instructional contact hours taught by the department. The formal instruction portion was obtained from the K-factor analysis, where it was assumed that the departmental budget was divided between formal instruction and graduate supervision.

$$\begin{array}{c}\text{total departmental}\\ \text{teaching equivalents}\end{array} = \begin{array}{c}\text{total departmental}\\ \text{contact hours}\end{array} + K \times \begin{array}{c}\text{number of graduate students}\\ \text{assigned to the department}\end{array}$$

$$\frac{\begin{array}{c}\text{total departmental}\\ \text{staff-contact hours}\end{array}}{\begin{array}{c}\text{total departmental}\\ \text{teaching equivalents}\end{array}} = \begin{array}{c}\text{departmental}\\ \text{instruction}\\ \text{factor}\end{array}$$

$$K \times \frac{\begin{array}{c}\text{number of graduate students}\\ \text{assigned to the department}\end{array}}{\begin{array}{c}\text{total departmental}\\ \text{teaching equivalents}\end{array}} = \begin{array}{c}\text{graduate student}\\ \text{factor}\end{array}$$

Note that:

$$\begin{array}{c}\text{departmental}\\ \text{instruction}\\ \text{factor}\end{array} + \begin{array}{c}\text{graduate student}\\ \text{factor}\end{array} = 1.0$$

Then:

$$\begin{array}{c}\text{departmental instruction}\\ \text{cost per staff-contact}\\ \text{hour}\end{array} = \frac{\text{departmental budget} \times \begin{array}{c}\text{departmental}\\ \text{instruction factor}\end{array}}{\text{total departmental staff-contact hours}}$$

$$= \frac{\begin{array}{c}\text{departmental budget}\\ \text{per F.T.E. staff member}\end{array}}{\begin{array}{c}\text{total departmental staff-contact}\\ \text{hours per F.T.E. staff member}\end{array}} \times \begin{array}{c}\text{departmental}\\ \text{instruction}\\ \text{factor}\end{array}$$

Three policy variables now emerge:

1. Departmental budget per F.T.E. staff member — departmental salary load. (This terminology is used because the major proportion of departmental budgets is salary.)
2. Total departmental contact hours per F.T.E. staff member = departmental instruction work load.
3. The departmental instruction factor.

These variables can be averaged for all departments within the faculty to yield:

$$\text{faculty instruction cost per staff-contact hour} = \frac{\text{faculty salary load}}{\text{faculty instruction work load}} \times \text{faculty instruction factor}$$

where: $\text{faculty salary load} = \text{faculty budget per F.T.E. staff member}$

$$\text{faculty instruction work load} = \text{total faculty staff-contact hours per F.T.E. staff member}$$

$$\text{faculty instruction factor} = \frac{\text{total faculty staff-contact hours}}{\text{total faculty teaching equivalents}}$$

Staff-contact hours per student

Two additional policy variables now are introduced:

4. Faculty student load = yearly hours devoted by students in any program to classes taught within the faculty.
5. Faculty average class size — measured as the ratio of the number of students in any section to the number of staff teaching the section, but averaged over all classes given within the faculty. For example, in a lecture section of 100 students, the class size would be 100; whereas in a laboratory section of 100 students with ten instructors, the average class size would be ten. (The average class size can be regarded as the average student/staff ratio in all classes taught in the faculty for any year of a program.)

For faculty classes in any program:

$$\text{faculty average class size} = \frac{\text{average yearly class hours per student} \times \text{number of students}}{\text{faculty staff-contact hours}}$$

so that

$$\text{faculty staff-contact hours per student} = \frac{\text{faculty student load}}{\text{faculty average class size}}$$

This expression applies only to classes taught within the faculty, but an identical equation can be derived for classes taught by other faculties where the student load and average class size then would apply to the latter classes.

Cost per student

Within the faculty, the unit cost of a program is:

$$\text{faculty cost per student} = \text{faculty instruction cost per staff-contact hour} \times \text{faculty staff-contact hours per student}$$

Since the unit costs of other faculties were a multiple of these costs for Engineering (using relative student/staff ratios), when the staff-contact hours per student for all faculties are added together, the total cost per student is roughly proportional[4] to this expression. Thus

$$\text{average cost per student} \propto \frac{\text{faculty salary load} \times \text{faculty instruction factor} \times \text{student load}}{\text{faculty instruction work load} \times \text{average class size}}$$

where:

student load = yearly hours devoted by students to classes taught by all faculties averaged over all engineering programs in any one year.

average class size = the ratio of the number of students in any section to the number of staff teaching the section, for classes taught by all faculties averaged over all engineering programs in any one year.

The expression employs five policy variables, and can be used as a management tool to control the costs of undergraduate programs. The definitions for student load and average class size can be restricted to specific programs, or expanded to cover all years in all programs. Also, salary load, instruction work load and the instruction factor can be examined at the departmental level.

For graduate programs, three components of unit cost were computed: instruction, graduate supervision and assisted research. The factors affecting instruction costs are similar to those for undergraduate programs, except that it is not possible to define a student load since both master's and doctoral programs were combined, and course work for these programs normally is not structured. Instruction contact hours per student vary directly with the number of instruction hours taken by each student, and inversely with the class size. Whereas class size can be measured readily, it would take an immense amount of effort to establish the instructional hours taken by each student, because it would be necessary to identify the classes taken by each graduate student. For this reason, no attempt was made to analyze graduate student instruction costs. Furthermore, the instruction costs for graduate students were only a small proportion of their total costs (5.5% average in Ontario).

Graduate supervision costs vary directly with the graduate student factor defined above, and on the average, represent 55% of total graduate student costs in Ontario. The balance consists of assisted research and university overhead.

In all programs, the final result was obtained by adding university overhead costs, expressed as a percentage of costs derived from faculty and departmental operating budgets, and assisted research. This is called the "university overhead factor", and constitutes another policy variable.

Table H-1 is a summary of the policy variables affecting unit costs for both undergraduate and graduate students. The total unit cost for undergraduates, where programs were aggregated by year in each university, varies over a range of 17:1. Only the average class size has a variation in this same range; all of the other policy variables span a range of lesser magnitude. For this reason, a regression was attempted in order to relate undergraduate total unit cost and average class size. This is shown in Figure H-1, where, as expected, the least-squares fit is a hyperbola. The correlation coefficient of the linear transform was 0.89, and a total of thirty-nine points were used, corresponding to each undergraduate year taught during 1969-70 in the eleven universities. A multiple regression to relate all of the policy variables to total unit cost was not attempted.

The second most significant policy variable was the faculty instruction factor, which varied over a range of 4:1. This factor defines the relative emphasis placed on instruction as opposed to graduate supervision, and becomes most important when comparing the relative costs of graduate and undergraduate studies in any university.

Next were the faculty salary load and faculty instruction work load variables, each spanning a range of about 3:1. Both of these variables depend on the number of F.T.E. staff within Engineering, and errors could have been introduced in the way they were reported by each university and counted for the purposes of this study. Fortunately, this counting does not affect

[4] The exact relationship is developed in CPUO Report 70-3.

unit cost calculations, since the number of F.T.E. staff cancel in the division of these two factors. The remaining policy variables, university overhead factor and student load, swing over a range of about 2:1, and so were the least influential.

It should be noted that student load and instruction work load are not entirely independent. For example, if the academic year was extended by an extra week, both policy variables would increase in equal proportion. On the other hand, should extra classes be added to the student load, then the instruction work load may or may not increase; the extra staff load could be accommodated either by adding more staff or by increasing the work load of the existing staff.

The dominant impact on graduate student costs, excluding assisted research, was the graduate student factor. This resulted from the K-factor analysis which concluded that each graduate student used 150 staff hours per year—an average for all the engineering schools in Ontario. Where there is a relatively large number of course-work master's students, compared to thesis master's and doctoral students, unit costs would be disproportionately high. The reverse may be true where graduate thesis students predominate.

Assisted research accounts for about 40% of the total unit costs for graduate students and includes income from many sources. This additional cost would apply only to thesis students. It is an external policy variable, principally under the control of the National Research Council, which provides the major source of funds in response to proposals for research grants from the universities.

Policy variables can be used as a tool to control unit costs. Such control may be exercised at any or all of the three levels — university, faculty and department.

(1) *Salary load* — Since the major portion of a departmental budget is salaries, this quantity reflects the mixture of senior and junior staff in the department. Generally, it increases with the age of the school as more staff achieve the rank of associate or full professor. However, within limits, a degree of control can be applied that is consistent with good instruction. For example, the use of part-time teaching staff from the profession should influence the factor in a downward direction.

(2) *Instruction work load* — It is recognized that there is only limited control of this variable because of tradition and normal university practices. The use of junior and part-time teaching staff, again as consistent with good instruction, tends to increase this variable, and thus to lower unit costs.

(3) *Instruction factor* — This factor, with its complement, the graduate student factor, establishes the relative emphasis between undergraduate and graduate studies. A low instruction factor shifts the expenditure to the graduate school, and requires a value judgment to make such a split. The instruction factor decreases as the number of graduate students increases, and the result is that fewer hours can be devoted to instruction for a fixed total staff work load. This creates a need to reduce the number of sections, and so the final result is larger class sizes usually in the first and possibly the second year. Again, the policy variables reveal some interdependency.

(4) *Student load* — This quantity exhibits the least amount of variation. Each engineering program would tend to involve students in comparable class instruction times, because of traditions and accreditation requirements. Some of the variation may be accounted for by differences in the number of weeks in the academic year among the universities. Any adjustment of this variable must result from a value judgment related to the number of hours a student should spend in class as opposed to other activities.

(5) *Average class size* — This is the most important policy variable and is influenced by two major factors: sectioning policy in the first and second years, and class proliferation in the third and fourth years, resulting from program expansion and the increasing number of elective classes. In both instances, a value judgment is necessary to establish reasonable upper and lower limits. The use of the average class size concept provides a quantitative basis for assessing the impact of basic sectioning and elective policies on unit costs.

(6) *University overhead factor*—It was assumed that this factor is beyond the direct control of the engineering staff.

(7) *Graduate student factor* — This is the complement of the instruction factor, and has been covered under (3) above.

(8) *Assisted research load* — In general, assisted

research makes graduate programs possible. Therefore, this factor is of crucial importance not for its effect on unit costs, but for its influence on engineering graduate studies. This matter is dealt with in some depth in Chapters 4 and 5 of this report.

The above policy variables give some insight into the influence of policies and practices on unit costs. What they do not give is an indication of quality. It is always possible to minimize unit costs, and the art of good management is to do so without adversely affecting quality. Thus, the elasticity of quality with each of these policy variables becomes a value judgment for each university.

COST AND SIZE

Table H-2 is a summary of average total unit costs by discipline and year, weighted by the appropriate number of students. For this reason, these averages represent true costs as opposed to the averages in Table H-1, where each university was given equal weight for the purpose of developing the policy variables.

In general, in any program unit, costs increased with the year, principally because of the decrease in average class size in the later years, as illustrated in Table H-3. This reduction in class size is caused by decreasing enrolments due to attrition and the proliferation of optional classes in many programs, particularly in the third and fourth year.

Table H-3

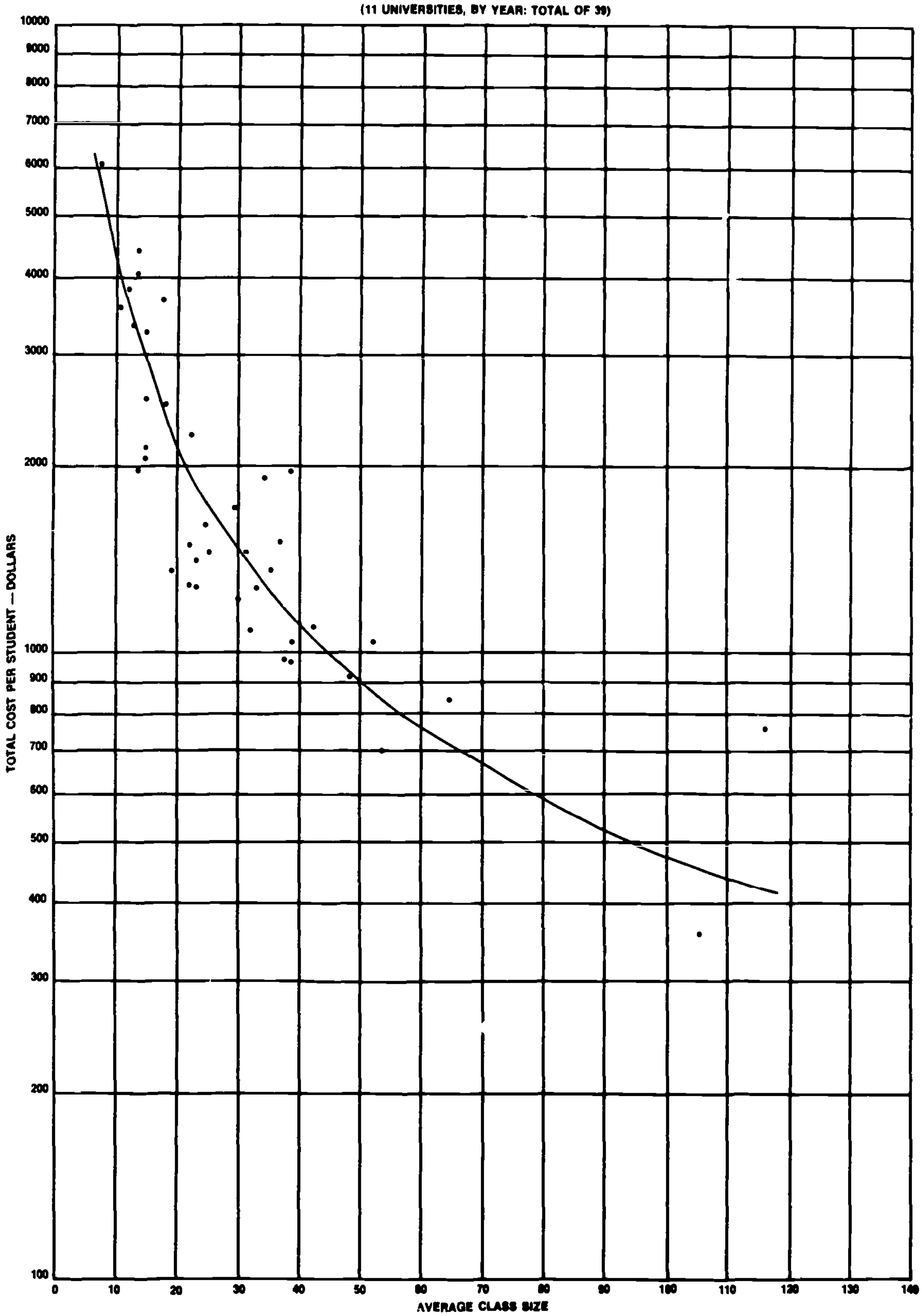
Undergraduate Year	Average Class Size (Ontario)	Number of Students in Sample
1	54.5	2,621
2	34.3	2,450
3	21.3	1,709
4	19.9	1,446
All	32.0	8,226

One important product of the cost study was the effect of engineering school size on unit costs. Figure H-2 is a cost-size comparison, and shows how the unit cost varied with the number of students in undergraduate programs (eleven universities) It is difficult to draw firm conclusions with such a small number of points, but a trend appears to emerge: the curve exhibits a minimum band between 600 and 1,300 undergraduate students. Below this band, classes are small because they are student-limited. Within the band, classes reach a critical size, where sectioning becomes necessary. Beyond the band, sectioning policy is the main determinant, and as the school becomes very large, there appears to be a tendency to section into smaller classes. In the larger schools, more elective classes are offered in the third and fourth year and this tends to keep average class size down even though total student numbers are relatively large.

From Table H-2, it is possible to estimate very roughly the expenditure required for an engineering degree. A crude attrition model is assumed as follows: 75% second-year survival from first year, 85% third-year survival from second year, 90% fourth-year survival from third year and 95% degree survival from fourth year. A conditional probability calculation was carried out using this model for the class of 1970. In round numbers, the expenditure to produce a graduate engineer in 1970 was about \$8,000. provided the structure developed in the cost study did not alter appreciably over the previous three years.

If attrition and discount are neglected for graduate students, the additional expenditure for a master's degree achieved in one year after the bachelor's degree was \$8,190 (a total of about \$16,000). For a Ph.D. achieved in four years after the bachelor's degree, there was an additional expenditure of \$33,000 (a total of \$41,000), excluding assisted research, or an additional expenditure of \$54,000 (a total of \$62,000), including assisted research.

Figure H-1 — AVERAGE CLASS SIZE — COST REGRESSION
ONTARIO ENGINEERING UNDERGRADUATE CLASSES 1969-70
(11 UNIVERSITIES, BY YEAR: TOTAL OF 39)



CORRELATION COEFFICIENT
OF THE LINEAR TRANSFORM, $r = 0.89$

LEAST SQUARES FIT:
$$\text{TOTAL COST PER STUDENT} = 64.7 + \frac{41{,}708}{\text{AVERAGE CLASS SIZE}}$$

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Figure H-2 — COST — SIZE COMPARISON
ONTARIO ENGINEERING SCHOOLS 1969-70

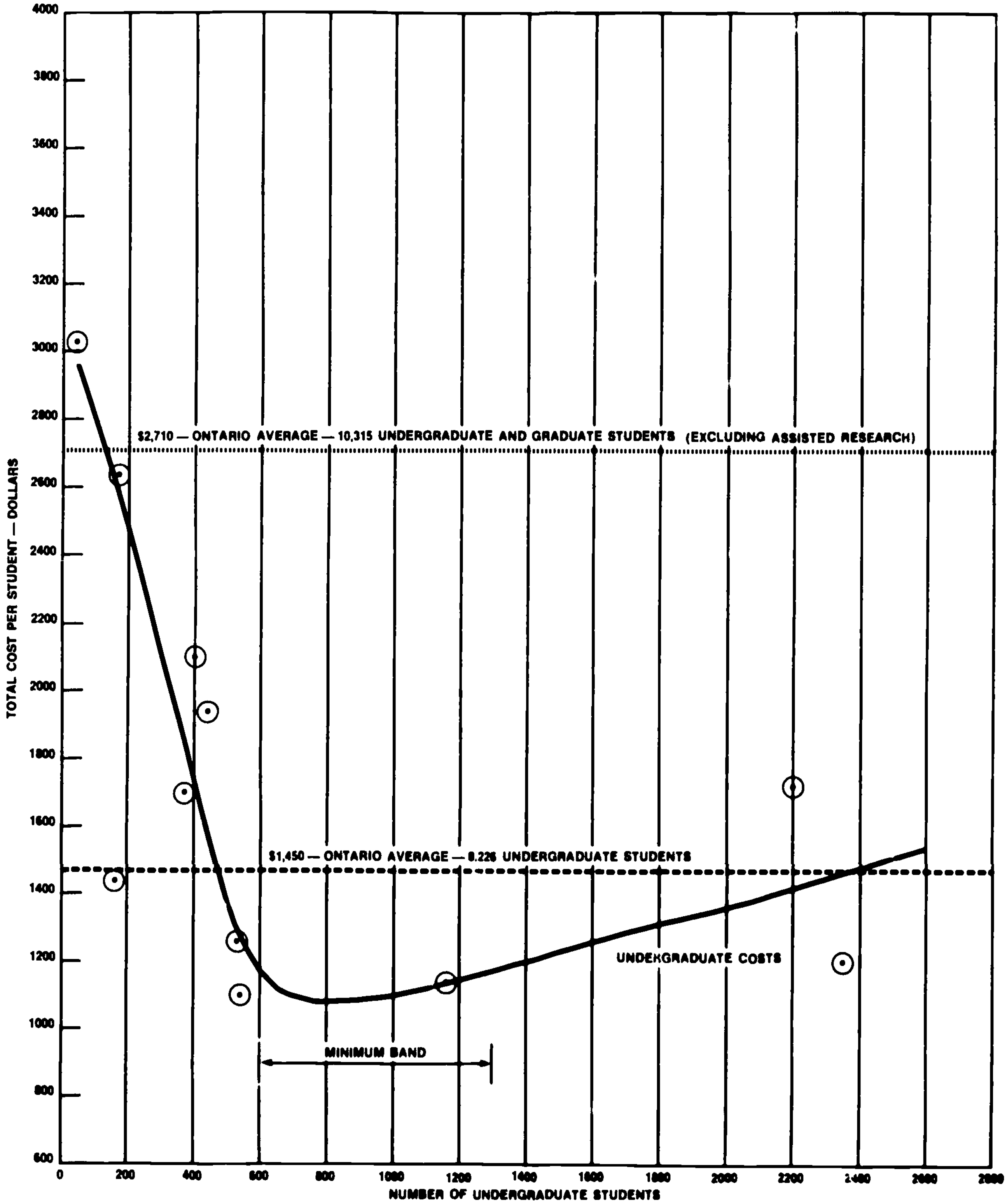

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Table H-1

Policy Variables – University Averages

1969-70

No.	Policy Variable	Affects Unit Costs	Units	Averaged Over	Year	Ontario Average	Maximum	Minimum	Maximum Minimum
1.	Faculty Salary Load	Directly	$ per F.T.E. staff	11 Universities	All	25,845	39,049	15,000	2.6
2.	Faculty Instruction Work Load	Inversely	Contact Hours per F.T.E. staff	11 Universities	All	293.96	495.89	157.71	3.1
3.	Faculty Instruction Factor	Directly	%	37[1] Departments	All	39	59	15	3.9
4.	Student Load	Directly	Student Hours per Year	11 Univ.[2]	I	734	819	637	1.3
				10 Univ.	II	652	736	514	1.4
				9 Univ.	III	673	769	583	1.3
				9 Univ.	IV	691	801	574	1.4
				11 Univ.	All	689	819	514	1.6
5.	Average Class Size	Inversely	No. of Students per Instructor in Class	11 Univ.	I	51	116.4	25.9	4.5
				11 Univ.	II	32.8	63.8	7.5	8.5
				9 Univ.	III	21.3	36.5	12.9	2.8
				9 Univ.	IV	19.9	31.8	10	3.2
				11 Univ.	All	32.3	116.4	7.5	15.5
6.	University Overhead Factor	Directly	%	11 Univ.	All	30	38	21	1.8
	Total Unit Cost Undergraduate		$ per Student	11 Univ.	I	1,110	1,960	360	5.4
				10 Univ.	II	1,670	6,080	700	8.7
				9 Univ.	III	2,140	3,360	1,170	2.9
				9 Univ.	IV	2,450	4,020	1,080	3.7
				11 Univ.	All	1,820	6,080	360	16.9
7.	Graduate Student Factor	Directly	%	37 Departments	All	70	79	62	1.3
	Total Unit Graduate Excluding Assisted Research	Instruction	$ per Student	37 Departments	All	1,090	2,410	90	26.8
		Graduate Supervision			All	9,460	14,860	3,860	3.8
		Total			All	10,550	17,000	4,370	3.9
8.	Assisted Research	Directly	$ per Student	35 Departments	All	6,350	20,420	1,600	12.8
	Total Unit Cost — Graduate Including Assisted Research		$ per Student	35 Departments	All	16,900	35,290	8,100	4.4

[1]37 departments had graduate students in 1969-70.
[2]Of 11 universities one offered years I and II only, and one offered year I only.

Table H-2
UNIT COSTS BY DISCIPLINE, YEAR AND NUMBER OF STUDENTS
1969-70

Program	Year	No. of F.T.E. Students	Ontario Average	Maximum	Minimum	Maximum / Minimum
Chemical	I	444	$ 920	$ 1,740	$ 360	4.8
Engineering	II	383	1,200	5,490	530	10.0
	III	228	2,800	4,660	990	4.7
	IV	237	2,100	8,840	1,230	7.2
	All	1,292	1,550	8,840	360	24.6
Graduate – excluding	All		9,190	14,730	5,760	2.6
assisted research		320				
– including assisted	All		15,740	20,800	11,440	1.8
research						
Civil	I	495	1,090	1,740	360	4.8
Engineering	II	505	1,500	5,980	980	6.1
	III	339	1,450	2,780	750	3.7
	IV	243	2,040	6,310	840	7.5
	All	1,582	1,440	6,310	360	17.5
Graduate – excluding						
assisted research	All	376	8,850	14,350	6,680	2.1
– including						
assisted research	All		14,110	23,120	9,820	2.4
Electrical	I	540	1,060	1,430	360	4.0
Engineering	II	560	1,010	1,500	700	2.1
	III	392	1,380	4,020	1,200	3.4
	IV	317	1,660	4,150	890	4.7
	All	1,809	1,220	4,150	360	11.5
Graduate – excluding						
assisted research	All		8,150	13,700	4,370	3.1
– including		413				
assisted research	All		12,180	19,510	8,800	2.2
Mechanical	I	529	1,050	1,430	360	4.0
Engineering	II	549	1,250	1,700	530	3.2
	III	366	2,010	3,320	940	3.5
	IV	322	1,800	6,020	1,000	6.0
	All	1,766	1,450	6,020	360	16.7
Graduate – excluding						
assisted research	All		9,410	15,270	6,400	2.4
– including		273				
assisted research	All		14,190	15,780	9,910	1.6
Metallurgical and	I	61	930	1,430	360	4.0
Materials	II	61	1,520	2,560	880	2.9
Engineering	III	33	3,940	6,120	210	29.1
	IV	38	6,850	14,460	4,470	3.2
	All	193	2,800	14,460	210	68.9
Graduate – excluding						
assisted research	All		10,450	17,000	7,190	2.4
– including		100				
assisted research	All		21,780	35,290	15,180	2.3
All Engineering	I	2,621	1,030	1,960	360	5.4
Programs	II	2,450	1,270	18,760	530	35.4
	III	1,709	1,850	6,120	210	29.1
	IV	1,446	2,040	14,460	840	17.2
	All	8,226	1,450	18,760	210	89.3
Graduate – excluding						
assisted research	All		8,190	17,000	4,370	3.9
– including		2,089				
assisted research	All	10,315	13,460	35,290	8,100	4.4

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APPENDIX I

QUESTIONNAIRE SENT TO ONTARIO FACULTIES OF ENGINEERING

PART A — FACTUAL DATA

1. GENERAL

Please state as concisely as possible your major goals and objectives in engineering education at your university.

In addition, it would be helpful to include your response to the CUA request of October 1968 calling for goals and requirements to 1975 which was sent to all Ontario universities.

2. CURRICULUM DATA

For the purpose of this question, the following definitions are arbitrarily stated:

Class — a subject given under a single title for a single term. (Lectures and/or laboratory and tutorial). Classes may be divided into *Sections* for teaching convenience.

Course or Undergraduate Program — a compilation of classes leading to the bachelor's degree.

Graduate Program — a body of work, including classes leading to a postgraduate degree. *Option* — a prescribed group of classes within an undergraduate program.

a) *Undergraduate*

i) Classes available and class sizes: this question is intended to confirm data available from the Calendar, together with quantitative data needed for size considerations. Figure 1 is a generalized layout for undergraduate courses. Please create such a diagram for your faculty, showing years and appropriate blocks corresponding to the required and elective classes for each undergraduate year. Each block should be numbered or coded for use in filling out Table 1.

ii) Table 1 is intended to be a comprehensive listing of undergraduate classes in which engineering students are enrolled in your university. It will reveal data on class sizes, teaching load, cross-faculty loading and enrolment trends. It is designed in such a way that it should be universal, and the data should be in a form that is immediately useful to this study.

Explanatory notes are appended to the Table, and an example is presented for a rather complex case to bring out most of the detail in a form that is expected.

iii) Please list those engineering undergraduate elective classes offered in your Calendar for which there is zero enrolment for the 1969-70 academic year.

iv) *Undergraduate Curriculum Committee*

a) Please describe the organizatioal structure of this committee, its membership, and its terms of reference.

b) What are the processes whereby changes are ultimately introduced into your curriculum?

c) What resources does this committee have at its disposal?

d) Have you developed a "product description" or specification for your curriculum? If so, please include in your response.

e) Have you developed formal criteria for evaluating proposed curriculum changes? If so, please include in your response.

f) Please describe recent activities of this committee and any planned future changes or developments in your undergraduate curriculum.

v) What influences have there been on your curriculum of any recent changes in attitude of other departments providing only service to engineering students?

vi) How has the local community influenced your engineering curriculum?

vii) Have the CAATS had any influence in your recent curriculum planning? If so, please state.

viii) Are you contemplating or currently involved with any inter-university class or course activity? If so, please state.

ix) Do you offer part-time studies, leading to a bachelor's degree? If so, please state details and number of such students in the 1969-70 academic year.

b) *Graduate*

i) Please list graduate programs and degree offerings in engineering, including OCGS appraisal status. Include any new graduate programs being planned, or in development, that would be subject to appraisal.

ii) Please construct Table 2, Graduate Classes 1969-70, using the same format as Table 1 but omitting Column 1. Include in this table *all* classes given by staff of the Engineering Faculty administrative unit, and those classes taken by students enrolled for a graduate degree in engineering outside of the Engineering Faculty administrative unit.

For graduate theses, list degrees separately (i.e. M.A.Sc., M.Eng., Ph.D., etc.) and use the Tutorial heading in Columns (7), (8) and (9). It is recognized that the contact and staff hours, in Columns (8) and (9) respectively will be estimated averages only; an indication of the spread in these columns should be included under Remarks, Column (11).

iii) Please list those graduate elective classes given by the staff of the Engineering Faculty administrative unit, offered in your Calendar for which there is zero enrolment for the 1969-70 academic year.

iv) In addition to the faculty loading related to formal classes and theses shown in Table 2, most graduate students consume further informal contact time of the engineering faculty. Please estimate this *additional* time in terms of hours per academic year (1969-70) per graduate student for each engineering graduate degree offered.

v) Please describe any inter- and intra-faculty and inter-university graduate programs in existence or planned, whether subject to OCGS appraisal or not.

vi) Please state the residency requirements in each of your engineering graduate programs. Include in your response any off-campus or cooperative programs.

vii) Please describe the formal and informal relationships that exist between the Faculty of Engineering and the Faculty of Graduate Studies. Where and how do they intersect administratively, and how is the control of specific classes and programs effected? In graduate programs, how do Department Heads relate to:

a) The Dean of Engineering?

b) The Dean of Graduate Studies?

vii) Do you offer an engineering Master's degree program which does not require a thesis or design project? If so, what percentage of students elect such a program in recent years? Are these primarily part-time students?

3. ENROLMENT DATA

a) Please list undergraduate and graduate enrolment figures by program on an academic year-by-year basis, for the past ten years. For each year the enrolment figures should apply at the December 1st date. Please use the format of Table 3. List special and interdisciplinary degrees separately in the first column, where practical.

b) Please display your enrolment projections both undergraduate and graduate, in the form normally presented, and describe the method used. How accurate have these projections been in the past? Could you indicate this accuracy by comparing your past projections with the data in Table 3? What will be the influence of the CAATs?

c) With respect to your enrolment for the 1969-70 academic year specify the number of *additional* students you could accommodate in each undergraduate year and all graduate years *without* adding either more staff, space or equipment.

Table 1

UNDERGRADUATE CLASSES 1969-70

Block Codes (R or E)	Class No.	Class Title	Given by Staff of the Dept. of	No. of Sections	Given to Students of the Dept. of	Number of students from each Department Lect.	Lab.	Tut.	Total annual contact hours per student Lect.	Lab.	Tut.	Total annual staff hours per section Lect.	Lab.	Tut.	Trends in total No. of students in recent years Rising	Stable	Decr.	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)			(8)			(9)			(10)			(11)
3 - R	101	Org.	Chem.	2	Chem.	38	38	3	30	90	60	30	360	60	*			Physics students
7 - E		Chem.	Eng.		Eng.	15	15											entering this
					Chem.	3	3											class first time
					Physics	10	10											this year as an
					Mater. Eng.													elective.

Notes on example: Organic Chemistry 101 is required in Chemical Engineering, but is an elective in Materials Engineering shown as Blocks 3 and 7 (for example) in your diagram. Students from the Departments of Chemistry and Physics are also enrolled in this course which is given in two sections. The Physics students are also given a tutorial. On the assumption that the class is given for 30 weeks, each student receives one hour lecture and three hours laboratory, with Physics students receiving an extra two hours tutorial per week. There is one lecturer and one member of staff giving the tutorial, but four staff members supervise the laboratory.

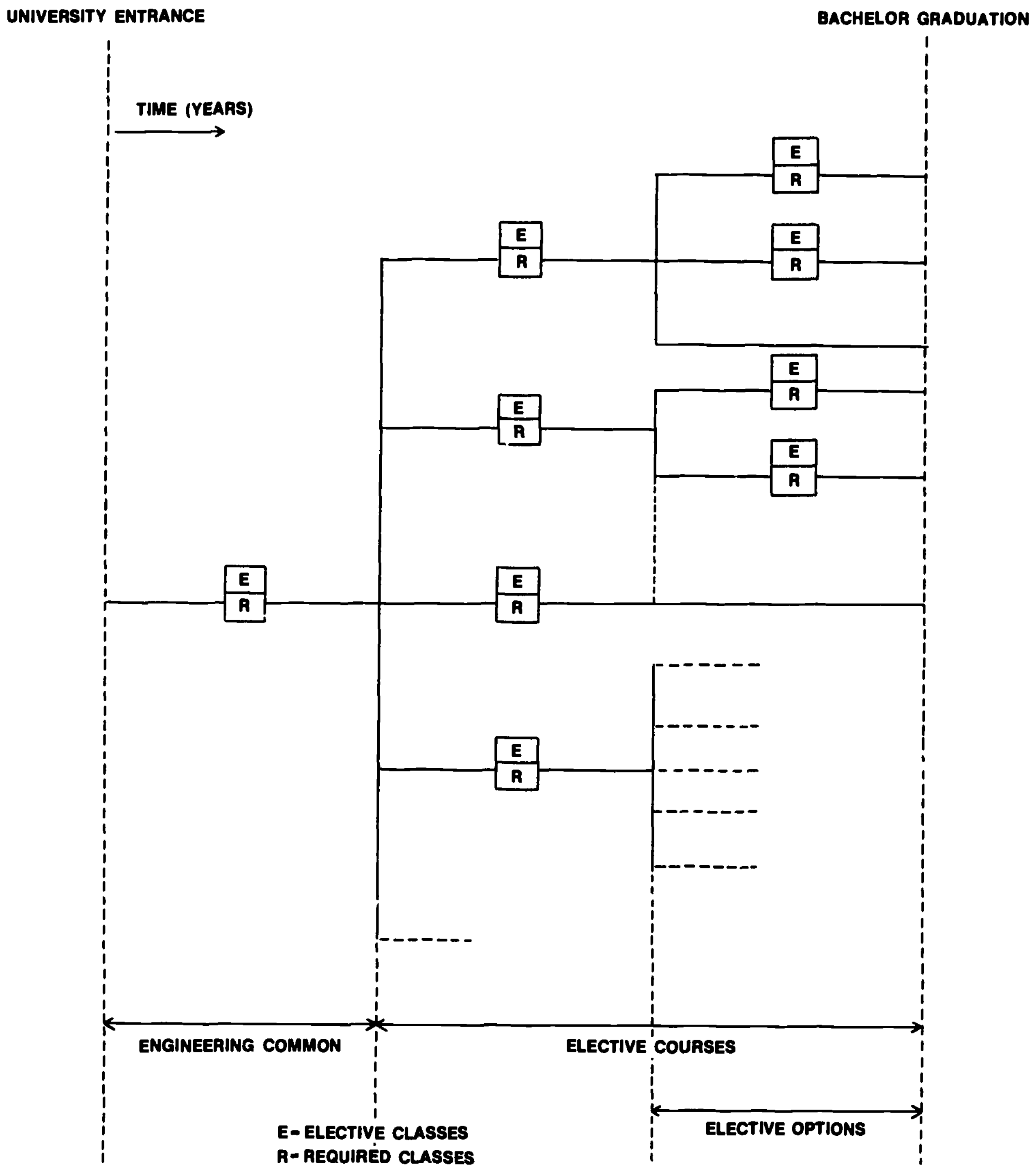

Figure I-1 — UNDERGRADUATE COURSE LAYOUT FOR ENGINEERING STUDENTS

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NOTES ON TABLE 1

(1) In your undergraduate curriculum diagram (Fig. 1) you have designated a code for each block. Please enter the applicable Block Codes for each class, and indicate whether or not it is a required or elective class (R or E).

(2) Enter the Class Number you normally use in your Calendar.

(3) Enter the Class Title you normally use in your Calendar.

(4) Include all Departments within the Engineering Faculty administrative unit together with classes of other Departments outside of the Engineering Faculty administrative unit in which engineering students are enrolled for the 1969-70 academic year. Classes should also be included that are given by members of the Engineering Faculty administrative unit where enrolment is entirely composed of non-engineering students.

(5) Number of Sections is the number of subdivisions of the class irrespective of the Department of origin of the students.

(6) This column covers the Department wherein the students are normally registered. For students not registered in a specific Department (such as first year students in most universities) state which faculty only.

(7) The number of students from each Department (or Faculty) should be shown opposite the relevant unit in column (6), under lecture, laboratory or tutorial — whichever the case may be.

(8) This can be obtained by multiplying the number of hours per week for each student by the total number of weeks that the class is given for the academic year 1969-70.

(9) This can be obtained by multiplying the total annual contact hours per student (Column (8)) by the number of staff utilized per section from the Department indicated in Column (4).

(10) & (11) These columns are intended to give an indication of enrolment trends and any *unusual* features related to 1969-70 enrolments in each class. Also in Column (11), state any unusual expense items that may be associated with this class — if they are significant. In multiple-section classes, also indicate when any section contains less than 10 students in Column (11) together with any other remarks related to sectioning policy.

Table 3
ENGINEERING ENROLMENTS

PROGRAM		1960-61 F.T.	TOT.	F.T.E.	1969-70 F.T.	TOT.	F.T.E.
CIVIL ENGINEERING							
Undergraduate	Yr. 1						
	2						
	3						
	4						
Graduate	Yr. 1						
	2						
	3						
	4						
	Beyond 4						
Total Bachelor's Degrees Awarded	B.A.Sc.						
Total Master's Degrees Awarded	M.A.Sc.						
	M.Eng.						
Total Doctoral Degrees Awarded	Ph.D.						
CHEMICAL ENGINEERING							
.							
.							
.							
etc.							
.							
.							
.							

F.T. — Full-time students
TOT. — Total full-time plus part-time students
F.T.E. — Full-time equivalent students

d) What are your admission requirements, quota and other regulatory mechanisms for entrance into engineering from:

i) Secondary schools (by province and country),

ii) CAATs and CEGEPs,

iii) Other universities (undergraduate and graduate studies)?

e) Please describe your guidance counselling activities with the high schools, CAATs and CEGEPs. How do these activities relate to guidance procedures of other faculties, and how are they funded?

f) How many new CAAT and CEGEP graduates are enrolled this year (1969-70)?

4. RESEARCH AND SPECIAL GRADUATE PROGRAMS

a) Describe the operation of any disciplinary or interdisciplinary research institutes in which members of the Engineering Faculty participate. Please indicate history, size and resources. Also include any such institutes now in the planning stage.

b) Describe any research or special graduate study programs with:
   i) Other universities,
   ii) Government departments (both federal and provincial),
   iii) Industry,

c) What is the influence of the local community on research programs? More specifically, define the kinds of interaction between your faculty and industry (or government) in terms of:
   i) Exchange of staff.
   ii) Provision of consulting services,
   iii) Entrepreneurial involvement,
   iv) Other.

d) Define the areas of research in each department (and interdepartmental) that represent your major foci of effort. For each focus give the following data:
   i) The number and names of professorial staff actively working together in the focal area (no staff member should be assigned to more than one focal area).
   ii) The F.T.E. number of graduate students. post-doctoral fellows and technicians associated with the focal area in 1969-70.
   iii) The number of graduate degrees by category (master's, doctorates, etc.) granted in the focal area in 1967-68 and in 1968-69.
   iv) The number of refereed publications by the group for the focal area in 1967-68 and 1969-70. Give typical recent examples.
   v) The total research support in dollars per annum for the focal area (exclusive of university sources) for 1967-68, 1968-69 and 1969-70.
   vi) The number of patent applications for each focal area in 1967-68, 1968-69 and 1969-70.
   vii) The intensity of involvement of the staff group with industry and government in the focal area (reference (c) above). To calibrate this, assume each staff member has available one-half day a week out of five days to engage in outside activities. What fraction of this time resource of the group is so committed?

e) Define the extent of the research activity of your faculty which rests on the activity of individuals not included above.

f) To what extent are engineering research programs in your faculty part of larger regional or national projects?

5. TEACHING AND RESEARCH STAFF DATA

a) Please complete Table 4 for all members of staff included in the Engineering Faculty administrative unit.

b) Please provide the results of any surveys conducted on the time distribution of faculty members.

c) What amount of time do you feel is appropriate for the time of staff involved in service outside of university business under the headings:
   i) Professional?
   ii) Community?

   What amount of time is currently committed by your staff in these areas?

d) What are your policies concerning the consulting activities of staff and faculty consulting groups? Describe your enforcement techniques.

e) What are your sabbatical policies?

f) Please list details about staff who also hold outside positions of responsibility in industry and government.

g) For the past ten years, list for each year the following ratios for the Engineering Faculty administrative unit: (show both numerator, denominator and ratio in your response).
   i) Total undergraduate teaching staff/total number of bachelor's degrees awarded.
   ii) Total undergraduate teaching staff/total undergraduate enrolment as of December 1.
   iii) Total graduate teaching staff/total number of master's degrees awarded.
   iv) Total graduate teaching staff/total number of doctoral degrees awarded.

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Dept.	Name of Staff Member	F.T.E.	Title	Field of Specialization	Profess. Practice	Number of Years Teaching	P.D.F.	At Present Univ.	Last Degree Name of Degree	Year Obtained	Univ.	Year of Birth	Birth-place	Year Obtained Landed Immigrant Status	P. Eng.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)

Table 4
TEACHING AND RESEARCH STAFF DATA 1969-70

Notes on Table 4

(1) The department to which staff member is attached at your university 1969-70.
(2) Surname, first name and initial of staff member.
(3) Full-time equivalent of staff member — use your own definition for this (e.g. for half-time member, enter 0.50; for full-time member, enter 1.00).
(4) Title refers to Dean, Vice Dean, Professor, Assoc. Professor, Asst. Professor, Adjunct Professor, Visiting Professor, Lecturer, Sessional Lecturer, Instructor, or other (please specify).
(5) Field of Specialization refers to specialty within his branch of engineering (e.g. "control systems" — within Elect. Eng.).
(6) Number of Years of Professional Practice (industry or other), not including academic or teaching experience.
(7) Number of Years of Academic Teaching, not including graduate study years unless these include time as an instructor or lecturer where he was responsible for one or more classes.
(8) Number of Years as a post-doctoral fellow — where applicable.
(9) Number of Years on staff of present university (irrespective of rank or title).
(10) Name of highest degree obtained.
(11) The year in which this degree was obtained.
(12) The university at which this degree was obtained — if outside of Canada, include country.
(13), (14) are self-explanatory.
(15) Where applicable, the year that the staff member obtained his landed immigrant status in Canada.
(16) State whether or not the staff member is a P.Eng. (yes or no).

h) What are your patent policies with respect to inventions of university staff and students?

i) What are your policies in respect to the use of university laboratories by staff for consulting purposes?

6. STUDENTS DATA

a) Please complete Table 5 for the five years shown, or for as many years as records are available. (The last row in this Table is intended to give an indication of the number of students whose parents or guardians are taxpayers in Ontario).

b) For the 1969-70 academic year students who are landed immigrants, as shown in Table 5, how many became landed immigrants *after* first registration with the university. Show this as the number of such students in each undergraduate year, and all years for graduate students.

c) Please provide any recent reports or statistics on student placement services for engineers in your university. Include any remarks you would care to make concerning the placement of graduate students, particularly Ph.D.'s.

d) What techniques do you apply to trace the career histories of your graduates? Please be specific, and include any *summary* reports in your response.

e) How do you guide students selecting their elective courses, options and classes? What form of career counselling do you provide?

f) Describe the student engineering societies on your campus; provide a list of such societies and their major activities.

g) Please indicate the percentage of your full-time engineering graduate students who receive support during the 1969-70 academic year as follows:

Federal government	%
Provincial government (direct):	%
University:	%
Other agency:	%
No support:	%
	100.0%

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Table 5

STUDENTS DATA

		1965-66						1969-70					
		Undergrad					G	Undergrad					G
		1	2	3	4	Tot.	All Yrs.	1	2	3	4	Tot.	All Yrs.
Sex	Male												
	Female												
Citizenship	Canadian												
	U.S.												
	Commonwealth												
	Other												
Landed Immigrants													
Secondary School Education	Ont.												
	Que.												
	B.C.												
	Prairies												
	Maritimes												
	U.S.												
	Commonwealth												
	Other												
Number *Eligible* for Ontario Student Loan													

7. CONTINUING EDUCATION

a) Do you offer classes in continuing engineering education; if so, what are your basic policies, goals and objectives? Are these classes offered through the Extension Department; if so, what are the formal and informal relationships between that Department and the Faculty of Engineering?

b) Please list your class, course and program offerings (including certificates and diplomas).

c) Enrolment statistics: Provide these in a form most convenient for your university, for the current year only but indicate any trends that are significant.

d) How do you allocate resources to continuing engineering education? Give an indication of costs and sources of funds, and the percentage of these costs covered by the normal faculty operating budget.

e) How do you cooperate with industry, government and the professional societies in continuing engineering education?

f) What methods of programming do you use (early morning, evening, weekends, etc.)?

g) What methods of class presentation do you use (CCTV, CATV, talk-back TV, audio-visual, etc.)

8. FACILITIES AND COSTS

a) Provide a brief description of major research facilities used by engineering students and staff ("Major facilities" is intended to mean those facilities which *you* consider major — no specific dollar value is intended).

b) What facilities do you currently share with other universities?

c) Please provide equipment replacement costs (Inventory as of January 1, 1970) under the following headings:
   i) Teaching,
   ii) Research,
   iii) Both teaching and research.

(Note: A separate cost study is being conducted, so that further cost data are not being collected here.)

PART B — OPINION

The following questions are an open list calling for expressions of opinion in certain key areas of the Engineering Study. They are intended only as a guide to manoeuvre the briefs from each University towards common problems. They are based primarily on the original CODE document, dated November 1, 1968.

Please indicate whose opinion is being presented.

1. a) What is your definition of engineering?

   b) What responsibility should the engineering schools assume for continuing education?

   c) Do you have any facts or opinions on the job-creating ability of engineers in the economy? How can this be measured quantitatively?

   d) In your opinion, is there a meaningful way to predict manapower demands for engineers? How would you go about it? How many years ahead is practical?

   e) How should proper allowance be made for business, applied arts and humanities in engineering curricula? Indicate your opinion as to their relative degree of importance in respect to engineering, science and technical subjects.

   f) Is the entrepreneur a product of an educational experience, or are other factors of greater significance?

   g) What role should women play in the profession?

   h) What is your feeling about the relative importance and relevance of course-work "professional" master's and doctoral programs vs. research-oriented graduate work?

   i) What is your reaction to the heavy emphasis now growing in the U.S. on computer-aided design? Should this be stressed more in Canadian schools — what are the pros and cons?

   j) Aside from the effects on enrolment, CAAT graduates will likely alter the future role of the engineer. Would you estimate how these relative roles will rationalize, and the impact this may have on future engineering curricula?

   k) It has been suggested that the output of a university is far more sensitive to the input than to the curriculum. If this is so, then screening techniques on entrants to university becomes a strong measure of output quality, and possibly more important than curriculum considerations. Would you comment on this statement?

2. ENGINEERING IN THE UNIVERSITY

   a) Should engineering schools be part of a university, or are there good reasons to establish separate polytechnical institutes?

   b) Should engineering be altered to be closer to a liberal education in undergraduate years?

   c) Should engineering subjects be offered to liberal arts students?

   d) In your opinion, is there a meaningful way to predict manpower demands for engineers? How would you go about it? How many years ahead is practical?

   e) Is there a case for using seasoned engineers as laboratory assistants and demonstrators instead of graduate students — so that students have a greater opportunity to "brush with the real world"?

3. DEVELOPMENT OF ENGINEERING EDUCATION SYSTEM IN ONTARIO

   a) Do you believe the present APEO accreditation system is meaningful?

   b) Could you suggest possible alternative means of accreditation which would ensure adequacy from a professional viewpoint, and yet provide sufficient scope for individuality, diversity and local community needs?

   c) What are your views on the cooperative system and its applicability to your university?

   d) Are there too many engineering schools in Ontario?

   e) What is the probable trend of engineering enrolments and will the population of Ontario schools remain fairly level?

   f) In your opinion what is the minimum size for an engineering school to be viable? What are your criteria for setting this minimum size?

   g) Do you believe it is practical to collaborate and rationalize engineering education among the universities in Ontario?

   h) How do *you* feel about sharing facilities, staff and other resources with other universities — is this *really* practical?

   i) Is there merit in collaborating with the CAATs in joint university/college programs (e.g. air pollution studies now being developed by Western and Fanshawe) ?

j) Do you believe that the classical subdivisions of engineering are now relevant? What alternatives would you propose?

k) Do you believe there is a case for a common undergraduate curriculum leading to a general bachelor's degree in Engineering, with specialization during the graduate years? (As per ASEE Engineering Goals Report — current recommendations.)

l) What influence do you expect from the growth of the CAATs on your enrolments and student flow patterns? Ruminate on your answer to question 3 (b) in Part A.

m) Are we close to 5-year programs, particularly if grade 13 is phased out?

n) If you were given the position of designing a completely new Ontario engineering school, with the only constraint that you accept students at the present grade 13 graduation level, what would you do?

o) What do you regard as your most vexing problem?

APPENDIX J

STUDY VISITS

Throughout the course of this study, visits — 132 in all — were made to a wide variety of organizations in Canada, the United States and abroad. We are indebted to many people who contributed time and provided hospitality in the course of our travels. For many of these institutions (for example, the Ontario universities), several visits and discussions were necessary. The following is a list of institutions that were visited, or whose personnel were interviewed in connection with the study.

Universities

Ontario — Brock University
Carleton University
University of Guelph
Lakehead University
Laurentian University
McMaster University
University of Ottawa
Queen's University at Kingston
University of Toronto
Trent University
University of Waterloo
University of Western Ontario
University of Windsor
York University
Royal Military College of Canada

Other Provinces University of British Columbia
University of Alberta
University of Saskatchewan
University of Manitoba
Ecole Polytechnique
University of New Brunswick
Nova Scotia Technical College
Memorial University of Newfoundland

United States — Dartmouth College
Massachusetts Institute of Technology
University of Buffalo
Stanford University
University of California at Berkeley
University of California at Irvine
University of California at Los Angeles
Harvey Mudd College

Other Canadian Educational Institutions

Ryerson Polytechnical Institute
Seneca College of Applied Arts and Technology
Mohawk College of Applied Arts and Technology
Thornlea Secondary School, Thornhill

University Organizations

Committee of Ontario Deans of Engineering
Ontario Council on Graduate Studies
Numerous other committees of the Committee of Presidents of Universities of Ontario
Institute for Quantitative Analysis in Social and Economic Planning
Ontario Institute for Studies in Education
Association of Universities and Colleges of Canada
Committee of Presidents of the Colleges of Applied Arts and Technology

Government

Federal — Office of the Privy Council
Science Secretariat
Science Council
Senate Committee on Science Policy
Economic Council of Canada
Dominion Bureau of Statistics
National Research Council
Defence Research Board (including establishments in Ottawa and Valcartier
Department of Communications
Department of Manpower and Immigration
Department of Energy, Mines and Resources
Department of External Affairs
Department of Industry, Trade and Commerce
Department of Transport
Department of Regional Development
Canadian International Development Agency

Provincial — Department of University Affairs
Committee on University Affairs
Commission on Post-Secondary Education
Department of Education—Colleges of Applied Arts and Technology and Curriculum Section
Department of Trade and Development

Industry — H. G. Acres Limited.
Canadian General Electric Company Ltd.

Canadian National Railways
Du Pont of Canada Limited.
The Foundation Company of Canada Limited.
Garrett Manufacturing Limited.
General Motors of Canada Ltd.
The Hydro-Electric Power Commission of Ontario.
Imperial Oil Limited.
International Nickel Company of Canada, Limited.
Kates, Peat, Marwick & Co.
MacMillan Bloedel Limited.
Noranda Mines Limited, Research Centre.
Northern Electric Company Ltd.
RCA Limited.
Sinclair Radio Laboratories Ltd.
Spar Aerospace Products Ltd.
Steel Company of Canada Limited.
Systems Research Group.
Canadian Chemical Producers Association.
Canadian Pulp and Paper Association.
Electronic Industries Association of Canada.
Lakehead Industrial Advisory Committee.
Laurentian Industrial Advisory Committee.

Professional Associations

Canada — Association of Professional Engineers of Ontario (including chapters in Thunder Bay and Sudbury).
Canadian Aeronautics and Space Institute.
Canadian Council of Professional Engineers.
Canadian Institute of Mining and Metallurgy.
Canadian Organization for Joint Research.
Canadian Society of Electrical Engineers.
Canadian Society of Mechanical Engineers.
Chemical Institute of Canada.
Engineering Institute of Canada.
Ontario Association of Certified Engineering Technicians and Technologists.
Ontario Engineering Advisory Committee.

United States — American Society for Engineering Education
Engineering Council for Professional Development
Engineers Joint Council — Engineering Manpower Commission
National Academy of Engineering

Other Organizations and Individuals

Technical Service Council
Iranian Ministry of Education
U.S. Department of Commerce — Science and Technology
Sir Eric Ashby — Cambridge University
Dr. Allen Rosenstein — University of California at Los Angeles

ENGINEERING EDUCATION IN EUROPE

The director of the study group visited Germany, France, Sweden and Great Britain in order to gain some perspective on the pattern of engineering education overseas, and on whether or not experience in Europe might be related to Ontario. The structures in European technological education are changing rapidly, and consequently the situation in these countries will soon be different from what was observed during this tour in March 1970.

There is a complex web of pathways between their various schools and programs and these have mostly been omitted. Each system has its own historic roots, and each institution has its own flavour. We have attempted to compare technological and engineering educational systems in these countries with that of Ontario (Fig. J-1). The diagram has been greatly simplified and illustrates only the main routes to a degree or diploma. The top bar represents the main stream leading either to a diploma in technology or its equivalent; the bottom bar is the normal direct route to a degree in engineering. The various alternative paths or cross-flows between the technological and engineering streams are not shown.

FEDERAL REPUBLIC OF GERMANY

Education in West Germany is the responsibility of the provinces (Länder) of which there are eleven (including the city-states of Berlin, Bremen and Hamburg). A new Ministry of Education and Science has been given the power to establish national educational and research guidelines, even though each Land still operates independently. This development should mean new patterns for German education, but it is too early to speculate on these changes.

All educational paths in West Germany start with four years at the Volksschule, commencing at the age of six. Students entering an Ingenieurschule (I.S.) usually attend Realschule for six years, and then devote two years to practical training in an industrial firm (Praktikum). Normally, admission to a course of study at a Technische Hochschule (T.H.) follows after nine years at Gymnasium, and a further half year of training in industry (Grundpraktikum).

The program at the Ingenieurschule is of three years' duration leading to the title Ingenieur (Grad.Ing.). Instruction has a practical slant, in order to fit students for professional work directly associated with operations and construction. The Technische Hochschule is the university of the technical sciences. The curriculum is 8-9 terms in length and leads to the Diplom-Ingenieur (Dipl.Ing.). However, in practice, it takes most students 10-12 terms, owing to numerous exercises and the extent of laboratory work. Advanced study involves special courses of lectures following the Dipl.Ing. plus a thesis which leads to the academic degree of Doktor-Ingenieur.

The following establishments were visited:

- Verein Deutscher Ingenieure (VDI) — the Association of German Engineers and host for the visit to Germany;
- Staatliche Ingenieurschule für Maschinenwesen in Krefeld;
- Staatliche Ingenieurschule für Maschinenwesen in Düsseldorf;
- August Thyssen-Hütte A.G. in Duisburg-Hamborn and their training school for I.S. and T.H. students in Düsseldorf;
- Technische Hochschule in Aachen.

The West Germans have developed a very close relationship between industry and their technical education system. Each I.S. has been established to serve a specific local industry, and 140 of them are located principally in industrial centres spread throughout the eleven provinces and city-states. These schools are dedicated to the training of engineers for operations, as opposed to research and development. Their curriculum lays stress on technological subjects, with a strong emphasis on basic mathematics and science. Approximately two hours a week is devoted to humanities and social sciences (8%), but both the students and industry have been pressing for more concentration in these areas. Training courses in industry are heavily structured, stressing artisan skills and operations procedures. At Thyssen, certain production and factory components are channelled through the training school.

There are nine T.H's and two universities (Regensburg and Bochum) offering programs leading to the Dipl.Ing. Since these programs stress research and development, there is a heavy emphasis on mathematics and science and very little humanities or social science content in the curriculum. Each major engineering discipline is centred on a senior professor, often in the form of an institute. Student/staff ratios are high (typically 30-40:1), and professors must have had industrial experience before their academic appointment. At Aachen, with a faculty of approximately 300, there are 165 chairs in engineering, while students number 11,000 of which 770 are doctoral candidates. Thus, there are more engineering students at Aachen than in all of Ontario's engineering schools. Contacts with industry are very close, being facilitated by regular symposia conducted through the industrial and professional associations, and by the appointment to honorary professorships of engineers in industry who devote one or two days a week to teaching. Some doctoral theses are conducted in industry. In a typical institute, the source of funding is divided equally among the Ministry of Education (Lander), the federal ministries in Bonn, the research association Deutsche Forschungsgemeinschaft and industry.

The Association of German Engineers (VDI) was founded in 1856 and since that time has been a potent force in engineering affairs. Present membership is 60,000, and it admits not only graduates from the I.S.'s and the T.H.'s, but also affords membership to those who have gained engineering status by meeting certain experience and academic qualifications. Today there are 330,000 engineers in West Germany, consisting of approximately 75% Grad.Ing.'s and 25% Dipl. Ing.'s. Recent flows into the engineering pool are of similar proportions: 20,000 Grad.Ing.'s and 7,000 Dipl.Ing.'s annually.

The VDI is attempting to develop equal status between the Grad.Ing. and the Dipl.Ing., even though the two spend different lengths of time in school. The VDI claims their function in the economy is a better basis for comparison, and that many Grad.Ing.'s hold senior positions. In the words of Dr. I. W. Lehmann of the German Association of Technological Societies (Deutscher Verband Technisch-Wissenschaftlicher Vereine) "the Dipl.Ing. ensures that the wheels of tomorrow turn, whereas the Grad.Ing. ensures that the wheels of today turn." This has been a matter of some concern in the European Common Market (ECM) where there is an attempt to permit engineers qualified in one country to practise in another. In February 1970, the ECM stipulated that this freedom of movement and practice for uni-

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versity graduates (i.e. the T.H.'s) be extended to Grad.Ing.'s and similar categories in the other member countries.

It is hazardous to draw comparisons between the graduates of two educational systems but, in a general way, the Grad.Ing. falls between a diploma technologist and a baccalaureate engineer in Ontario, while a Dipl.Ing. is roughly comparable to an Ontario engineer with a master's degree. Thus, the I.S.'s are the equivalent of our CAAT's and the T.H.'s of our degree-granting engineering schools.

A recent development in Germany is the proposal to integrate the present I.S.'s into one university comprising all possible disciplines (Gesamthochschulen), in order to give them university character. In the words of Dr. F. Meyer, Chairman of the VDI, "the creation of a unified professional grade — whether that of a Diplom Ingenieur or that of a differently named one — is justified, without regard to the nature and duration of the educational route followed." For both types of engineers ,the VDI is advocating a three-year common core program in fundamentals coupled with practical experience and technical training, to be followed by required and elective studies in specific disciplines based on the students' aptitudes and abilities. Whether or not such proposals are acceptable, the barriers which have been created by the nature and duration of education are being slowly dismantled as new criteria are developed for professional recognition in the Federal Republic of Germany, the most industrialized nation in Europe.

FRANCE

In France, the responsibility for public education lies with the Ministry of National Education, although a number of other ministries, such as agriculture, industry, and defence, exercise educational power and functions. Students proceeding to higher education take their baccalauréat examination after attending a lycée (classique or moderne). This allows them to enter two years of preparation classes (classes préparatoires aux grandes écoles) during which discipline is severe and competition keen for entrance into a grande école.

The grandes écoles are the engineering schools of France. Some of them date back to the eighteenth century and were founded by groups of specific industries which felt the need for trained engineers. One of the earliest was the Ecoles des Mines founded in 1783. New schools were created as industry progressed, and engineering education in France always has been closely coupled to industry even though today they are under a Ministry of National Education.

The program at a grande école is of three years' duration and leads to a Diplôme d'Ingénieur (the school is always designated after this title) . They are often referred to as two-plus-three schools — two years' preparation (in a lycée) , and three years at the school. The celebrated Ecole Polytechnique, established during the French revolution to form the main cadre of engineers, is a two-plus-two school. It is an élitist school from which most graduates enter the French civil service. Some move on to a grande école to become engineers, entering at the second year. Master's degree students in science also may enter at the second year. Attrition rates at the grandes écoles are very low because of the demanding entrance requirements. Advanced studies toward a doctorate can be pursued either at a university or at certain grandes écoles.

At the present time, there are 139 grandes écoles in France, with a total intake of approximately 8,500 a year, and the number is growing at the rate of 3 to 4% each year. Graduate engineers practising in France number 130,000, and an additional 60,000 hold engineering jobs by acquiring professional status through what the French call "social promotion" — they are examined and granted a Diplôme par l'Etat (D.P.E.) . Ministry officials claim that nearly 10% of all science baccalauréats enter engineering. Whereas ten years ago there was a shortage of engineers, today a sufficient number are being turned out to satisfy demand — as measured by starting salary increases and advertisements. There are said to be fewer than 500 unemployed engineers in France, and this is consistent with the number who would be changing jobs at any particular time.

Technologists are designated by the title Diplome Technicien Supérieur, awarded after a two-year program at a lycée technique following the baccalauréat, or a four-year program at a lycée technique. In 1965, the Institutes Université de Technologie (I.U.T.) were created to train more technologists and to serve the tertiary sector with specialists. Physically located in the universities, they also provide part-time studies leading to a Diplôme d'Etudes Supérieure Technique (D.E.S.T.) to serve those seeking social promotion. The I.U.T.'s graduate 5,000 engineering technologists annually to supplement the 12,000 coming from the lycées techniques. The ministry claims the annual requirement for engineering technologists is 40,000 (i.e. 4 technologists per engineer flowing into the labour force) .

The following establishments were visited:

Organization for Economic Cooperation and Development:

La Fédération des Associations et Sociétés Françaises d'Ingénieurs Diplômés;
Ecole Centrale des Arts et Manufacture, Chatenay-Malabry;
Ministry of National Education;
Ecole Nationale Supérieure Industries Agricoles et Alimentaires, Massy-Palaiseau, Le Noyez Lambert;
Ecole des Mines—Fontainebleau.

In the grande écoles, the usual curriculum is organized in the following manner:

50% science and technology,
15% laboratory,
20% humanities and economics,
15% industrial experience (stage).

Industrial experience varies from school to school, but in most of them it is gained during the months of February and March. Over a three-year period, most students receive five months of industrial training: the first year as an ordinary worker, the second as a supervisor and the third as an engineering assistant. Each school requires a short thesis which must be related to a specific industrial problem. In the words of the director of one school, "the basic theme in the curriculum is a mixture of practice and theory so as to mobilize their knowledge, and use what they have learned."

The student/staff ratio of a typical grande école is low — 6:1. The staff consists of full-time civil service professors, assistants and demonstrators, and part-time industrial professors. A typical teaching load amounts to 120 hours a year. Many civil service professors increase their income by industrial consulting.

Most schools have a Conseil de Perfectionment made up of members from industry, the university staff and the appropriate ministries. This group usually meets annually to review curricula and other educational matters, and to ensure that teaching programs are related to the needs of the industries served by the school.

Three types of doctorate degrees are awarded. The Doctorat d'Etat is a prerequisite to teaching in a French university. Many years of preparation and the contribution of two significant theses are required for this degree. The Doctorat d'Ingénieur usually requires a minimum of two years after the diploma and a thesis. A third degree known as the doctorate of the third cycle involves a shorter dissertation and can be earned in one year after the diploma.

In 1966, France passed an act taxing industries in proportion to their employment of highly qualified manpower in order to help cover the costs associated with continuing and adult education, refresher courses and re-training. Each company so taxed is granted relief on the basis of its own contributions to these areas. Again, while it is dangerous to draw comparisons, the Diplôma Technicien Supérieur would appear to be equivalent to a diploma technologist in Ontario, with the I.U.T. being an institution similar to a CAAT. There are wide variations in the Diplôme d'Ingénieur from school to school, but it would be roughly equivalent to an M.Eng. degree in Ontario.

The democratization of higher education in France has resulted in over 600,000 students attending university. Of the 139 grandes écoles, 48 have been established since the end of World War II. The growth of professional faculties has been very rapid and now they appear to be in trouble since there are insufficient jobs for their graduates. There is concern that France is over-producing engineers with its present annual flow of 8,500 into the labour force — estimated to be twice what is necessary to maintain the present pool of 130,000 graduate engineers at a constant size. On the other hand, the flow of technologists is thought to be only about one-half what it should be to meet current needs, and in some sectors of industry initial salaries for technologists are higher than for engineers — the average starting salary for an engineer is 1,700 francs a month, while a technologist to begin with will receive from 1,300 to 2,000 francs. This apparent imbalance in the production of engineers and technologists probably will require adjustment, and it is expected that changes in the present pattern will occur in the near future.

SWEDEN

Sweden is a country of 8,000,000 people—only slightly larger in population than Ontario. Standards of living are comparable, and so it should be of interest to compare respective education and manpower statistics. In this connection, it must be borne in mind that Ontario imports engineers to meet its needs, while Sweden has been more or less self-sufficient.

The Swedish educational system is state-controlled, with compulsory education in the grundskola extending for nine years up to age 16. The upper-level secondary school (gymnasium) gives each student access to higher education. It is divided into five streams: liberal arts, social sciences, economics, natural sciences and technology. Each stream takes three years except technology, which has an extra year and leads to a technology degree. Students preparing for engineering by way of the natural science and technology streams must take advanced courses in mathematics, physics and chemistry. Each student must develop a working knowledge of at least three foreign languages, with English being compulsory. At the secondary level, 50% of a student's time will be spent in humanities and social science subjects. (There are no so-called liberal learning subjects in the Swedish engineering schools.)

Post-secondary education consists of traditional university-level institutions: five universities, two institutes of technology, two independent schools of commerce and one independent school of medicine and dentistry. With the exception of the school of commerce, all are financed by the government. The central authority is the Office of Chancellor of the Swedish Universities. It is responsible to the Ministry of Education for the over-all planning and development of the nation's university system, as well as the educational content of the different courses of study so as to guarantee that universities provide education of an equal standard. In 1969-70 approximately 120,000 students were attending these institutions.

There are four engineering schools in Sweden that offer both undergraduate and graduate programs:

The Royal Institute of Technology in Stockholm,
The Chalmers Institute of Technology in Gothenburg,
The Faculty of Technology at the University of Lund, and
The School of Engineering at the Linkoping Institute of Higher Education.

In addition, there is a school of engineering at the University of Uppsala and engineering education at this university's branch in Orebro. Recently, it was proposed that some form of engineering education be provided in northern Sweden, possibly connected with the University of Umea.

An engineering degree is awarded after the successful completion of a four-year program of study at one of the above schools. The degrees are civil ingenjor, bergsingenjor (mining and metallurgy only) and arkitekt. Up until 1969, there were two higher degrees: the teknisk licentiatexamen, earned after a further five or six semesters of study, and a doctoral degree in technology. Now, there is to be only one doctoral degree, earned after a four-year period of study and exclusively research-oriented.

The institutions visited were as follows:

Svenska Teknologforeningen — the Swedish Association of Engineers and Architects;
The Royal Institute of Technology in Stockholm;
The Swedish Society of College Engineers (Gymnasium Engineers);
The Office of the Chancellor of Swedish Universities.

There were 9,326 undergraduate engineering students and 700 doctoral candidates in Sweden in 1969[1] (compared to 8,500 and 660 respectively in Ontario), with a freshman intake of 2,687 students. In 1968, 1,343 first degrees were awarded. At the present time, approximately 20,000 engineers are practicing in Sweden, and this number is expected to almost double over the present decade. These figures are comparable to those for Ontario.

The number of student places at each institution, and for each program, is established by government. The number of places available for new entrants in 1970 is shown in Table J-1. Enrolments in engineering experienced a slight decline in 1967-68, but were up again in 1969, when there were almost twice as many applicants as there were places (four times as many in technical physics and architecture). Admission is handled centrally, and the individual institute or school has no control over the admission of its particular students. An average of the secondary school record is used as the basis for entrance, with no extra weight being given to either mathematics or the natural sciences. This selection process is completely computerized.

Table J-1

FRESHMAN PLACES FOR SWEDISH ENGINEERING SCHOOLS — 1970-71

Technical Physics	270
Technical Physics (fourth-year entry)	30
Technical Physics and Electrical Engineering	170
Mechanical Engineering	617
Aeronautics	45
Electrical Engineering	495
Civil Engineering	490
Chemical Engineering	288
Chemical Engineering (third-year entry)	42
Mining	30
Metallurgy	80
Architecture	210
Surveying	70
Engineering Economy and Industrial Organization	110
Teacher training (Electrical Engineering)	80
Teacher training (Mechanical Engineering)	60
TOTAL	3,087

[1]Hans Larsson, *Development of Universities of Technology in Sweden*, Office of the Chancellor of Swedish Universities, January 1970.

Student/staff ratios are in order of 10-12:1. Professorial staff devote approximately 116 hours a year to lecturing. At one time the relationship with industry was very important, but today it is less so, since more professors come from the academic environment and new faculties of technology are developing within the universities. There are few dual posts where professors hold industrial appointments. Each professor supervises an average of 4.3 doctoral candidates, so that "productivity" is approximately one doctor per professor per year. Now there is concern that they may be overproducing doctorates in view of the number of available research positions — another situation comparable to Ontario.

At the Royal Institute, there are 80 separate institutes developed along lines similar to those observed in Germany. They are linked together by the academic curriculum, but separated for purposes of research and research grants. It is not unusual for staff within an institute or department to form a company within the confines of the university to undertake consulting, research and development. One such operation presently is exploiting a new product developed in university laboratories.

Technology education in Sweden, conducted principally in the technical gymnasia, is a four-year program leading to the Gymnasium Engineer. There are no examinations, but each student does receive a grade so that he may enter an engineering school if he wants to. Although 6,000 gymnasium engineers entered the labour force in 1968, the numbers have been increasing rapidly since then. Now, there are five gymnasium engineers entering the labour force for every graduate from an engineering school. As in Germany, the number of gymnasium engineers in senior positions is surprising. A survey conducted in 1967 indicates that over 10% of the gymnasium engineers held leading positions in industry, as compared to 43% for the engineering graduates covered by that study.

A Swedish educational commission, known as U68, was appointed in 1968 with the task of developing an over-all plan for post-secondary education. The report is to be issued in 1970, and its preliminary analysis leads to the idea that a period of work should follow immediately upon the conclusion of secondary school. The whole structure of post-secondary education would be based on the principle of recurrent education. U68 is expected to recommend that entrance requirements for engineering schools be relaxed considerably, only those requirements deemed absolutely necessary being retained. In the future, the concept of engineering education as a separate entity may disappear, to be replaced by an integrated university system having no formal boundaries between the different departments or faculties. Swedish industrialists have not reacted favourably to such a proposal, but many do claim that the exact content of education, especially in advanced technological subjects, is of little account in an age of rapid technological change. They are not in favour of lengthening the process beyond four years, preferring to acquire their engineers early and then devote time to in-plant training. Thus the academic community is faced with the problem of retaining a four-year program possessing a high degree of "age-resistance" to quote the term used by U68.

One way of attempting a solution to the problem of age-resistance is to increase steadily the number of basic subjects such as mathematics, physics and fundamental engineering in the program. Mathematics does give methodical training and is age-resistant, but such an approach has been attacked on the grounds that the future engineer will use it less and less in his career, and the age-resistance is of the wrong kind. Such subjects as basic physics are too well structured, train the engineer in wrong methods and become potentially dangerous when he encounters highly unstructured situations in the real world of engineering. A proposed alternative is to insist that after the student receives methodical training in depth in one area of engineering, he should take part in all aspects of real engineering problems and so assist in their solution, while obtaining the beneficial experience of working as a member of a team within a complex organization.

The conclusions of U68 have not been announced, but its major aim would appear to be the restructuring of post-secondary studies as a life-long educational process. This would result in Swedish education shifting from an approach where the teacher provides the student with some skills and knowledge, to a plan whereby the goal is to give the student an intelligent and efficient way of teaching himself.

GREAT BRITAIN

Much has been written about the present technical and engineering educational systems in Great Britain, and what follows is only a rough outline of some salient features. Secondary education begins at age 11 in a public, secondary modern, grammar or technical school. Students sit for examinations after five years and receive a General Certificate of Education at the Ordinary level (G.C.E - O level). Two years of further study normally are required for examinations at the

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Advanced level (G.C.E. - A level). For entrance into a degree program, the student must pass at least two A-level examinations in addition to three or more at the O level, or have acquired an appropriate Ordinary National Certificate or Diploma "at a good standard".

In 1963, the report of the Robbins Commission on Higher Education recommended a thorough reorganization of British higher education. For many years, colleges of technology and commerce had been providing courses at the degree level which led to a Diploma in Technology, a London University external degree, or a college diploma. Following the Robbins Report, the Council for National Academic Awards (CNAA) was set up as an independent institution to grant awards to students who successfully complete approved courses in colleges of technology and commerce, and other non-university institutes which did not have degree-granting powers.

In 1966 there were about fifty colleges in England and Wales with students on programs leading to degrees in scientific and/or technological subjects, three-quarters of them preparing students for the B.Sc. degree of the CNAA, and over half of them offering courses leading to an external degree from the University of London. A White Paper in that year (A Plan for Polytechnics and Other Colleges) recommended the establishment of thirty major institutions of higher education from the large number of technical colleges, colleges of commerce and colleges of art. One of their principal functions is the further development of courses in scientific and/or technological subjects at the degree level. These polytechnics have moved into the university system and are being funded by government on the advice of the University Grants Committee. At the present time, there are nearly 2,000 students at each polytechnic, a number expected to double by 1976 and to treble in the early 1980s, to reach a total of 200,000 students.

Both the universities and the polytechnics offer three-year programs leading to a bachelor's degree in engineering. (Scotland is an exception, with its bachelor degree programs being the traditional four years.) Also, there are the "sandwich" courses — a "thin" sandwich in which, over four years, students spend alternate periods of six months in industry and in school, and a "thick" sandwich involving periods of a year in industry before and after three years at university.

The training of technologists usually starts at the age of 15 in a local or area college while the individual is working part-time. At the end of one year, the student can transfer to a City and Guilds of the London Institute technician course, which requires a further four to six years; or at the end of the second year he can take an examination leading to a program for the National Certificate. There, he is joined by students with G.C.E.-O level standings in at least four subjects, including mathematics and science, and together, they will begin a part-time program terminating with the Ordinary National Certificate (O.N.C.) after two years, or the Higher National Certificate (H.N.C.) after four years. The H.N.C. is approximately equivalent to the technology diploma in Ontario.

The National Certificate system has been in operation in the United Kingdom for more than forty years and has attracted large numbers of students. Its principal drawback has been the time factor — a minimum of six years and often longer. Consequently, new programs are being developed to shorten the time involved — the Ordinary and Higher National Diploma which usually are sandwich courses at a local or area college with a higher entrance standard.

The following organizations were visited in Great Britain:
Ministry of Technology,
Institution of Electrical Engineers,
University of London, King's College,
Department of Education and Science.
City University,
University of Sussex, Brighton —
Institute of Manpower Studies.

Prior to 1967, City University was a college of advanced technology, but it became a technical university in that year. It operates on the thin sandwich system admitting students in September and February. The program is of four years' duration. There are 2,300 undergraduate and 200 graduate students, with a student/staff ratio of approximately 10:1. Work in the humanities and social sciences makes up about 10% of the curriculum.

British engineers are organized professionally in separate institutions, each concerned with a particular engineering specialty. A federal body was formed in 1962 which led to the establishment of the Council of Engineering Institutions. Its Charter provides for the designation of Chartered Engineer, and the initials C. Eng. may be used by fully qualified members of the fourteen constituent institutions. University and CNAA degrees in engineering normally are accepted as satisfying the academic standards for entry into the profession, but practical training and experience in a post of responsibility are further requirements. Many colleges offer courses for non-degree students which lead to the examinations of a professional institution, and holders of National Certificates are no longer exempt from these examinations.

There are approximately 200,000 engineers and technologists in the United Kingdom, comprising graduates and graduate equivalents (those who have satisfied the examination requirements of the professional institutions). University degrees awarded in engineering and technology are now in the order of 8,000 a year, and the number is rising rapidly, being supplemented by the CNAA degrees which should attain a rate of 2,000 a year in the early 1970s. A flow of technicians into the labour force has been maintained in the order of five O.N.C./O.N.D. and Certificate Technicians to every graduate, but the stock of technical supporting staff (approximately 700,000) is low in proportion to the stock of graduates and graduate equivalents. In the words of Lord Jackson: "... our annual output of qualified technical supporting staff . . . is inadequate. . . ."[2]

The Industrial Training Act of 1964 made provision for the establishment of industrial training boards, whose responsibility it is to see that amount and quality of training are adequate to meet needs at all levels of employment. They impose a levy on employers and have the power to pay grants to those who provide or secure training to meet the requirements of the Board. A firm that fails to provide for training must pay a levy but receives no grant from its Board. A firm which does more than its fair share of training may receive more back in grants than it pays in levies. For example, the Engineering Board imposes a 2.5%-on-payroll levy which raised £75 million in the first year. Originally, this Act was intended to cover non-degree training at the technical support level, but now it is moving into degree-level training. It is too early to predict its effect on the universities, but it may have an impact on the future of the sandwich-type programs.

[2]Lord Jackson of Burnley, *Manpower for Engineering and Technology*, First Annual Willis Jackson Lecture, British Association for Commercial and Industrial Education.

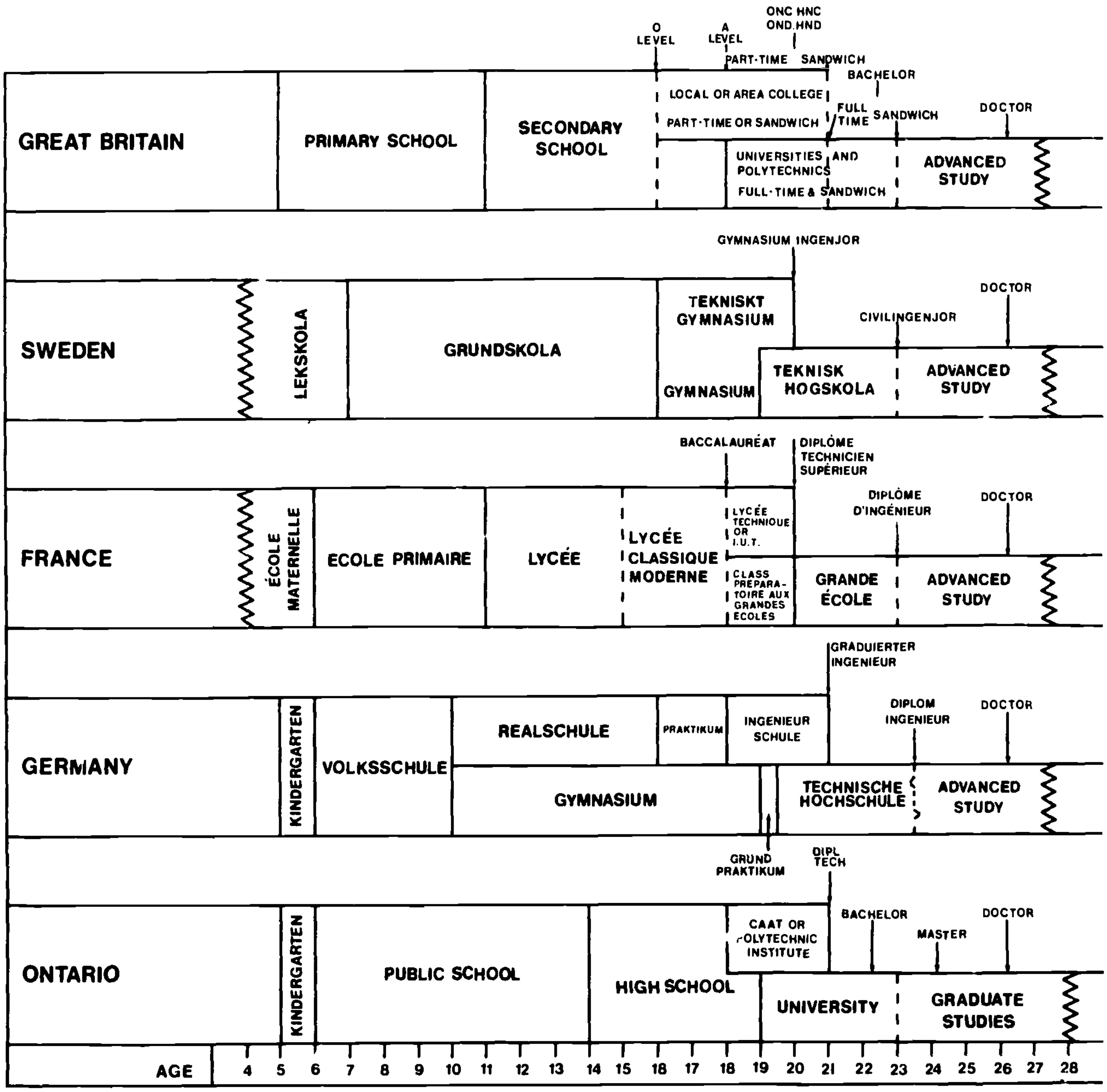

Figure J-1 – SIMPLIFIED TECHNOLOGIST AND ENGINEERING EDUCATION SYSTEMS – SELECTED COUNTRIES – 1970

PUBLISHED REPORTS OF THE COMMITTEE OF PRESIDENTS OF UNIVERSITIES OF ONTARIO

(Except *Student Participation in University Government*, which is out of print, and the *Inter-University Transit System Anniversary Report*, which is obtainable through the Libraries' Transit System Office, York University, reports are available from the University of Toronto Bookroom)

Post-Secondary Education in Ontario, 1962-70
1962. $1.00

The Structure of Post-Secondary Education in Ontario
1963. $1.50

The City College. 1965. $1.00

University Television. 1965. $1.00

The Health Sciences in Ontario Universities: Recent Experience and Prospects for the Next Decade. 1966. $1.00

From the Sixties to the Seventies: An Appraisal of Higher Education in Ontario. 1966. $2.00

System Emerging: First Annual Review (1966-67) of the Committee of Presidents of Universities of Ontario. 1967. $1.00

Student Participation in University Government: A study paper prepared for the Committee of Presidents by its Subcommittee on Research and Planning. 1968. (Out of print)

Collective Autonomy: Second Annual Review, 1967-68. 1968. $1.00

Ontario Council of University Librarians: Inter-University Transit System Anniversary Report, 1967-68. 1968. $1.00

Campus and Forum: Third Annual Review, 1968-69. 1969. $1.00

Variations on a Theme: Fourth Annual Review, 1969-70. 1970. $1.00

Ring of Iron. 1970. $2.00

Ontario Council on Graduate Studies: The First Three Years of Appraisal of Graduate Programmes. 1970. 50¢

PUBLISHED RESEARCH STUDIES BY THE COMMITTEE OF PRESIDENTS OF UNIVERSITIES OF ONTARIO RELATED TO THE STUDY OF ENGINEERING EDUCATION IN ONTARIO

(Available from the Secretariat of the Committee of Presidents, 230 Bloor Street West, Toronto 181)

CPUO Report No. 70-1	"Undergraduate Engineering Enrolment Projections for Ontario, 1970-1980," Philip A. Lapp. October, 1970.
CPUO Report No. 70-2	"An Analysis of Projections of the Demand for Engineers in Canada and Ontario and An Inquiry into Substitution Between Engineers and Technologists," M. L. Skolnik and W. F. McMullen. November, 1970.
CPUO Report No. 70-3	"A Method for Developing Unit Costs in Educational Programs," Ivor Wm. Thompson and Philip A. Lapp. December, 1970.

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