The University of Michigan
College of Engineering

# ENGINEERING EDUCATION AT MICHIGAN: CRISIS, CHALLENGE, AND OPPORTUNITY*

James J. Duderstadt, Dean

May 25, 1982

*Excerpts from presentations made during 1981-82

## 1. INTRODUCTION

There is a growing belief that engineering education will play an increasingly critical role during the next decade as both this State and the nation become ever more dependent on science and technology and therefore upon engineers. Today our nation faces an engineering manpower crisis of unprecedented proportions that poses the most serious implications for industrial productivity and national security. The strong demand for engineering graduates is continuing to accelerate along with student demand for admission to engineering programs.

There is also an increasing recognition of the importance of the role that the College of Engineering at The University of Michigan, as one of the leading engineering institutions in the nation, will play in the industrial and economic development of the State of Michigan. As Michigan industry strains to become competitive once again in the world marketplace, it will become increasingly dependent upon the availability of talented engineering manpower and the seeds for technological innovation provided by institutions such as the College of Engineering. Moreover, the State's efforts to diversify its economy by attracting new high technology industry to Michigan will be determined to a very large degree by the availability of high quality engineering programs.

Therefore it is with considerable alarm that we note the serious plight of engineering education in Michigan today. A decade of deterioration in State funding has dealt Michigan's leading engineering schools and colleges a crippling blow. These schools now find themselves straining to meet the intense needs of industry in this State for talented engineering graduates and creative research, even as the State budget cuts reduce even further what little public funding of engineering education still remains.

Despite the importance of its role both within this State and the nation, the College of Engineering at The University of Michigan finds itself today in a desperate struggle for its very survival. During the past decade, public support of the College has deteriorated to the point where it has become not only one of the most poorly supported major engineering schools in the United States, but for the past several years it has had the dubious distinction of being the most underfunded unit at The University of Michigan. Indeed, a careful analysis reveals that over the past decade, State support of the College has dropped effectively to zero. The College of Engineering has become, in effect, a "private" institution.

Yet the true costs of this decade of neglect have been very high indeed. The College now finds itself struggling to meet the intense needs of this State and nation for its students and the intellectual achievements of its faculty in the face of inadequate funding, obsolete laboratories, decaying physical facilities, and a seriously overloaded faculty. It has become painfully apparent that until this situation is corrected, the College will be severely handicapped in its efforts to achieve excellence, to maintain its traditional reputation as a leader in engineering education, to attract and retain outstanding faculty and students, and to respond to the serious needs of the State and the nation for its graduates and its research.

It is ironic and alarming that at just that moment in time when there is growing recognition of the importance that engineering education will play in rebuilding this State, we are proceeding to cut public support of this enterprise. This State is, in effect, dismantling the most distinguished of its engineering schools — the very institution that will (or at least could) play the key role in rebuilding the industrial productivity of Michigan.

My intent here is to alert you to the crisis surrounding engineering education in Michigan today. It is my belief that the College of Engineering at The University of Michigan has been forced to a critical juncture that jeopardizes the very future of this State. For without major and immediate relief, this State's leading engineering institution will drop rapidly in quality and capacity. Such an occurrence would severely impair this State's efforts to revitalize its industry and strengthen its economy.

The College of Engineering, as one of the truly outstanding engineering institutions in the world, represents a major resource to the State of Michigan. It would be tragic indeed if through lack of foresight and commitment this State were to allow this institution to deteriorate to a level that could no longer support Michigan's aspirations to rise once again to economic and industrial leadership in this nation.

## 2. THE NEED

It is no secret that American industry faces formidable competition in the world marketplace. We need look no further than our own industries in Michigan to see vivid evidence of this intense struggle for industrial survival. And we need look no further than this State to see the impact of this struggle on our society: almost one million Michigan citizens out of work, a state that is struggling to maintain badly needed social services while avoiding the catastrophic dismantling of distinguished institutions such as its universities.

Fortunately there is a growing recognition and commitment on the part of Michigan industry to those actions necessary to become competitive once again. The key here will be a major transition from experience-based to knowledge-based activities. This will require a massive infusion of high technology into Michigan industries if they are to regain a competitive edge.

As the hard lessons of the past several years have struck home, and Michigan industry has searched for ways to regain competitiveness, it has begun to recognize the importance of two critical factors in this task:

i) technological innovation

ii) technical manpower

In its search for these essential ingredients, industry has turned to the well-spring from which these flow, to Michigan's research universities, seeking their help to provide the intellectual creativity so fundamental to technological innovation, and the talented, broadly-educated engineers to implement these new ideas.

Michigan's schools and colleges of engineering represent a major resource to this State and its industry. These institutions have the capacity and commitment to respond to the needs of the State in its efforts to revitalize and diversify its industry. One need only look at examples such as Silicon Valley (surrounding Stanford and Berkeley), Route 128 (surrounding MIT and Harvard), and the Research Triangle (adjacent to North Carolina, North Carolina State, and Duke) to see dramatic evidence of the impact that quality engineering programs can have on industrial and economic development.

This fact has not been overlooked by Michigan's competitors in the Sunbelt. Many states, including Arizona, Texas, Florida, Georgia, New Mexico, Louisana, Alabama, and so on, are making massive commitments of public funds to build up their engineering schools and colleges to attract new industry. Yet, at least for the moment, we still have a lead in this critical area, for Michigan's engineering programs have firmly established reputations for excellence that place them far above those under development in these other states.

## 3. THE POTENTIAL

For over a century the College of Engineering at The University of Michigan has ranked among the leading engineering schools in the world, with claims to unusual strength across the full spectrum of technical interest. Founded in 1853, the College is the seventh oldest engineering school in the nation. It ranks third among all engineering schools in the total number of degrees awarded and claims more than 38,000 alumni throughout the world.

Each of the 19 academic programs offered by the College is currently ranked among the leading programs in the nation, whether evaluated with respect to the quality of undergraduate instruction, graduate instruction, or research accomplishment. In a recent survey conducted in 1980, 13 of the College's degree programs ranked among the top five in the nation. Nine of these programs ranked first nationally among public universities. This degree of both breadth of disciplines and depth of quality is unmatched by any other engineering school in this nation.

Several other statistics concerning the College are worthy of note:

Enrollment (1981-82):

| | |
|---|---|
| 4360 | undergraduates |
| 774 | M.S. students |
| 361 | Ph.D. students |
| 5495 | students (total) |

Graduates (1980-81):

| | |
|---|---|
| 997 | B.S. graduates |
| 464 | M.S. graduates |
| 54 | Ph.D. graduates |
| 1515 | graduates (total) |

Staffing and Facilities:

258 faculty
600 total staff
1,000,000 net square feet of laboratory space
$40,000,000 annual operating budget (essentially none of which comes from State support)

These statistics indicate quite clearly that the College of Engineering represents an important resource to both the State and the nation, a resource that can and should play a major role in revitalizing and diversifying industry through the creative activities of its faculty and the ability of its engineering graduates.

3.1. The Commitment

As a public institution (in fact, if not in funding), the College believes it has a major responsibility to respond to the needs of the State and the nation. Of particular importance is its commitment to respond to the needs of industry.

This is very natural for an engineering college. Industry represents our primary reason for existence. If we recognize that engineering is merely the application of science and technology to meet the needs of society, then it is apparent that industry is the manifestation of this activity. Conversely, our students and our research are the lifeblood of industry, and in my opinion, the key to the future of American productivity.

The College of Engineering intends to do its best to meet its responsibilities to industry. A major thrust of the College over the next decade will be a refocussing of its efforts on the needs of industry. We believe it particularly important that the College address the special needs of Michigan industries.

We are moving rapidly to develop and apply our strong capabilities in areas that respond directly to these needs:

i) computer integrated manufacturing (using computers and modern telecommunications to integrate all aspects of engineering design, manufacturing, and management)

ii) robotics and flexible automation

iii) computer-aided design and manufacturing (CAD/CAM)

iv) microelectronics, VLSI, and ULSI

v) computer science and engineering

vi) materials development and processing

vii) biotechnology

viii) applied areas such as aerospace, naval, and nuclear engineering

The College is also developing other mechanisms to interact more effectively with industry:

i) co-operative engineering education programs

ii) continuing engineering education (through its Engineering Summer Conference programs and its Instructional Television System)

iii) faculty/industry exchange programs

iv) Technical Advisory Councils (teams of faculty that provide technical advice directly targeted to the needs of a particular company)

Through such new programs the College is attempting to reach out to industry, to learn its concerns and needs, and to respond in an effective manner.

3.2. An Example: The Center for Robotics and Integrated Manufacturing (CRIM)

As an example of this renewed commitment to industry, let me describe the College's recent activities in the general areas of robotics and computer-integrated manufacturing. Roughly a year ago the Governor of Michigan appointed a special High Technology Task Force to provide assistance in identifying a suitable course of action to stimulate and diversify the economy of the State. The Task Force rapidly reached the conclusion that the most effective way to attract high technology industry to this State would involve the establishment of a "world-class" center of excellence in some particular area.

In Spring of 1981 the College of Engineering was asked to assist the Task Force by organizing a team of faculty to assemble a detailed plan for developing a world-class institute in the area of automated manufacturing or "robotics." Such an area of focus was particularly appropriate in view of Michigan's concentration of heavy manufacturing industry and its historical role in the development of automation. It was also compatible with The University of Michigan's traditional strengths in the areas of computer science and engineering, mechanical engineering, electrical engineering, and industrial engineering and operations research. The preliminary proposal prepared by the College was instrumental in assisting members of the High Technology Task Force in recommending the establishment of a major research institute in the area of industrial technology.

The College of Engineering realized at the outset of this study that the success of the proposed institute would require strong interactions with industry and relationships with other institutions throughout Michigan and the nation. However, it was also apparent that the institute would be uniquely dependent upon the resources of the College and the University in its efforts to attract a staff of outstanding quality and to establish the necessary relationships with graduate education and research so essential to success in high technology areas.

Therefore the College made a significant and substantial commitment to work closely with the proposed Industrial Technology Institute of Michigan, to assist it during its early stages of development, to coordinate its own faculty recruiting efforts with the major staff recruiting activities of the Institute, and to complement the activities of the Institute with the strong basic research and graduate programs conducted in the College.

To facilitate this interaction, the College moved rapidly to develop an organization that would interface with the Institute by drawing upon limited discretionary resources of the College and coordinating its ongoing activities in robotics, computer engineering, manufacturing engineering, and information management systems. In October of 1981 the Regents of the University approved the establishment of the Center for Robotics and Integrated Manufacturing (CRIM) to coordinate and expand the ongoing research activities of the College in areas concerned with the computer-based automation of the functions of industrial production including conceptual design, production design, testing, manufacturing, and delivery. An organizational structure was developed for the Center consisting of three divisions: i) Robotics Systems, ii) Integrated Design and Manufacturing, and iii) Management Systems. These divisions now coordinate the efforts of roughly 35 faculty across five departments of the College. The College further committed eight new faculty positions in areas related to Center activities. Additional funding has been sought and obtained from both federal and private sources that will sustain the activities of the Center at a level in excess of $2 million per year for the next several years.

The Center was designed to provide the close interface among the College, the University, and the Industrial Technology Institute. During the early stages of development of the Institute, we believe the Center will play a key role in providing for the necessary critical mass of technical personnel to conduct high quality research. Furthermore, since key staff members in the Institute are expected to have joint academic appointments in the College (while selected faculty and students of the College will have research appointments with the Institute), we believe the Center will play a critical role in assisting and coordinating the staff recruiting efforts of the Institute. Over the longer term we intend that the primary role of the Center will be directed at basic research and education that complement the applied research and development activities of the Institute.

The Center for Robotics and Integrated Manufacturing represents the commitment of the College of Engineering to respond forcefully to address the needs of the State of Michigan, to marshall its considerable resources to assist the State in establishing the Industrial Technology Institute, and thereby to assist the State in the critical task of strengthening and diversifying its economy. It is but one example of the potential of the College to respond effectively to meet the needs of this State and this nation.

## 4. THE CRISIS

I would be remiss, however, if I did not also indicate the difficulties that we face in this exciting endeavor — difficulties that now threaten both

the quality of the academic programs conducted by the College as well as its ability to participate in the economic revitalization of this State. For at just that moment when both the State and its industry are turning to the College for assistance in revitalizing Michigan, short-sighted actions and a decade of neglect have forced the College into a desperate struggle for its very survival.

Engineering education both in Michigan and throughout the nation has encountered a rather puzzling and frightening paradox. There is general agreement that the United States faces a technical manpower crisis of unprecedented proportions that poses the most serious implications for industrial productivity and national security. The demand for engineering graduates has never been more intense, as evidenced by the mobs of industrial recruiters that clog the corridors of the Placement Center and the starting salaries they offer to engineering graduates.

Furthermore there has never been a stronger demand on the part of students to become engineers. For the past several years the number of applications for admission to the College of Engineering has been growing at rates of 10 to 15% per year. There has been a similar trend in the quality of students seeking careers in engineering. The academic ability, enthusiasm, and commitment of undergraduate engineering students enrolling in the College today are extraordinary by any measure.

Yet, most engineering programs find themselves incapable of meeting this intense demand on the part of both industry and students. Indeed, essentially all of the major engineering institutions in the United States have been forced to limit engineering enrollments for several years. Even more disturbing is the fact that many of our most distinguished engineering programs (including the College of Engineering) will actually be forced to cut enrollments over the next several years.

This, then, is the paradox. At just that point in our history when this State and this nation are becoming increasingly dependent on technology and engineering manpower, those institutions such as the College of Engineering which must supply these graduates find themselves not only incapable of meeting this strong demand, but beyond that, are facing serious difficulties which threaten to dismantle this critical resource. The serious decline in public funding of engineering education, coupled with the increased shortage of engineering faculty, deteriorating physical facilities, and obsolete instructional equipment are factors bringing our system of engineering education to the brink of collapse. And this is occurring in the face of an unprecedented growth in the attractiveness of engineering careers to the best of our high school graduates.

### 4.1 The Demand for Engineering Graduates

As Michigan and the nation become increasingly dependent on technology to revitalize economic development and provide for national security, so too do they become increasingly dependent on an adequate supply of talented engineering graduates. The need for engineers is intensifying, both because of the increasing sophistication of the technology employed by our society as well as the growing importance of engineering in meeting other societal needs

(as the proliferation of regulations governing environmental impact, public health, and safety over the past decade have made apparent). While it is true that the quality of life and the economic well-being of our society depend on many factors, it is also true that these cannot be maintained, much less improved, without an ever-increasing supply of highly skilled engineers.

Several examples will illustrate this growing need for engineers:

i) This year in the United States, some 20,000 engineering positions went unfilled. The American Electronics Association is projecting a shortfall of more than 129,000 electrical and computer engineers by 1985. Other engineering fields such as chemical engineering, mechanical engineering, and industrial engineering are predicting similar shortfalls between supply and demand.

ii) This situation will intensify. Surveys of the projected engineering manpower needs of the largest corporations (e.g., GM, AT&T, Exxon, IBM, Ford) lead to requirements that exceed the capacity of all of our nation's engineering colleges over the next decade.

iii) Engineering schools have been sensing this pressure in their placement centers for several years. In Spring of 1982 typical B.S. level engineering graduates from the College of Engineering received 5 job offers at average starting salaries ranging from $25,000 to $30,000.

iv) The demand for engineers is likely to increase even further in future years as the nature of society's dependence on technology changes. As we have become more concerned with public health, safety, and environmental impact, we have created new regulations and institutions (EPA, OSHA, NRC) that require both industry and government to expand their engineering capabilities. Furthermore, the rapid introduction of intelligent automation in both factory and office will increase the needs for engineers and technicians, even as it displaces traditional blue collar and white collar labor.

v) This situation is particularly critical at the advanced degree levels. Engineering doctorates have declined from 3,774 per year in 1972 to a level of 2,751 in 1981. Projections are that this decline will continue to a level of 2,500 by 1987. Roughly half of these doctorates are received by foreign nationals. The high demand for B.S. graduates (as evidenced by their extraordinary starting salaries), coupled with the catastrophic deterioration in government funding of engineering graduate programs over the past decade, has cut the pipeline into the graduate programs.

vi) As a result of the marked decline in engineering graduate programs, there is now a crisis situation developing in the staffing of faculty positions in engineering colleges. A recent NSF study indicates that roughly 10% of the budgeted faculty positions in engineering are now vacant. In some critical areas the faculty shortages are far more intense. For example, in solid-state electronics, computer engineering, and digital systems unfilled faculty positions are closer to 50%, while in chemical engineering the shortage is estimated at 25%.

Most engineering institutions are now reporting a substantial decrease in their ability to recruit and retain engineering faculty.

vii) The faculty shortages will increase over the next decade as those engineering faculty hired during the massive expansion of engineering education in the 1950s reach retirement age, while engineering doctorate production continues to drop. It is now estimated that engineering faculty needs alone will require an increase of 1500 engineering doctorates per year (an expansion of 60%). This "turnover" in engineers will also occur in industry as those engineers educated during the 1940s and 1950s rapidly approach retirement age.

viii) It is now apparent that even if sufficient resources could be provided to allow engineering colleges to hire additional faculty to meet this State and nation's critical needs for engineers, the decline in engineering doctorate production over the past decade has depleted the pool of potential faculty members to the point where such a rapid expansion is simply not possible. (Here we should recall once again that many of this nation's leading engineering institutions are actually being forced to cut enrollments.)

ix) This situation stands in sharp contrast to the rapid increase in engineering graduate production in most other industrial nations. Indeed, the per capita production of engineers in the United States has now dropped to the lowest among the major industrialized nations. To illustrate, I have compared statistics for four different nations below:

| | Number Graduated | % of College Graduates |
|---|---|---|
| United States | 60,000 | 6% |
| Japan | 73,508 | 21% |
| USSR | 300,000 | 35% |
| West Germany | 120,000 | 37% |

As the president of Sony remarked in Fall of 1981, "In the United States you produce 4 lawyers for every engineering graduate. In Japan we graduate 4 engineers for every lawyer!"

4.2. Student Demand and Quality

Students are certainly not insensitive to this intense demand. The number of applications for admission to the College of Engineering is at an all time high. Because the standards for admission to engineering programs have become more selective relative to those of other fields, engineering students now represent the best students on campus.

For example, the average SAT entering score of students entering the College of Engineerng is now 1250. Almost 25% of our entering freshmen have high school grade point averages of 4.0, while 80% of them rank in the top 10% of their high school classes.

There has been a similar increase in both the quantity and quality of transfer admission (usually at the junior year). Each of the College's degree

programs now sets transfer admission grade point averages in excess of 3.0. In several cases such as Electrical and Computer Engineering these transfer grade point requirements have risen to 3.5.

It is fair to say that the quality of the undergraduates in the College has never been higher, nor has there ever been more demand on the part of highly motivated and talented Michigan high school students for admission to our engineering programs.

4.3 The Capacity to Respond

What has been the response of engineering colleges to the intense demand for their graduates coupled with the growing demand on the part of students to become engineers? Unfortunately, most engineering colleges have neither the faculty nor physical facilities to respond to this increased demand. Indeed, most of the largest and highly respected engineering schools in the United States have been limiting undergraduate enrollment for several years. Beyond that, several of the leading institutions (including Illinois, Purdue, Wisconsin, UCLA, and Maryland) have announced plans to dramatically cut undergraduate enrollments by 20% to 40% over the next several years. Many other institutions (including Michigan) are seriously considering similar actions.

The reason for this drastic action is quite simple: as public support of higher education in general — and engineering education in particular — has declined over the past decade, engineering colleges have found themselves struggling to meet the intense demand for engineers with inadequate funding, decaying physical facilities, obsolete equipment, and a seriously overloaded faculty. In the face of this catastrophic loss of public support, the leading institutions have decided that massive enrollments cuts will be necessary to preserve the quality and integrity of their programs.

Let me be more specific. The State of Michigan has long been renowned for its system of higher education. The flagship of this system (and, indeed, of public universities throughout the nation) is The University of Michigan. Yet over the past decade we have seen public support of higher education in Michigan drop to the point where the State now ranks 42nd in the nation in its level of state support per student. As yet another indication of how rapid and severe this drop has been, we would note that Michigan ranks 48th in the nation in the level of new support it provided to higher education over the past decade. In the period of less than ten years this State has dropped from a leader in its support of higher education to among the lowest in the nation.

This decline in state funding has fallen particularly harshly on engineering schools and colleges. Throughout most of the past two decades, the major share of new State support went to the health sciences (e.g., schools of medicine, dentistry, and nursing) or other professions (law and education). By the mid-1970s when engineering enrollments began to swell, the State began to encounter its serious economic difficulties and lost the capacity to respond to these enrollment increases. In most of this State's schools and colleges of engineering, there has been an enrollment growth of roughly 50% over the past 5 years accompanied by an actual decrease in State funding for engineering.

## 5. IMPACT OF THE CRISIS ON THE COLLEGE OF ENGINEERING

To give a vivid example, State funding of the College of Engineering at The University of Michigan declined in real terms at an average rate of 7% each year during the decade of the 1970s. This sustained erosion in public support, coupled with dramatic increases in tuition charges and sponsored research support has led to the ironic (and somewhat horrifying) situation in 1982 in which the College finds itself without any State support whatsoever. That is, the recovered income of the College ($40,313,934) from tuition, private gifts, and research contracts now exceeds its operating and capital expenditures ($40,186,591). In effect, a decade of neglect has forced the College to the stance of a private institution — in funding at least — and seriously damaged its capacity to respond to the needs of this State. Although this withdrawal of State support may appear to be a savings in the short term, in the longer term the cost has been very high indeed, since the State has come periously close to dismantling one of its most important resources — a resource that is expected to provide the technological innovation and technical manpower to rebuild the economy of Michigan.

Let me be more precise. Over the past decade the compound growth rate in University support of the College from its General Fund, when measured per student credit hour of instruction, has averaged less than 1% per year. This growth rate is several times lower than any other unit in the University. When inflation (e.g., through application of the Consumer Price Index for this period) is taken into account, the College experienced an average loss in General Fund support per Student Credit Hour over the decade of 7.6% per year. During this period, the instructional staff of the College dropped by 11%. Its staff of technicians was cut in half. And yet during this same period, enrollments in the College of Engineering increased by 44%, the number of Student Credit Hours of instruction it provided increased by 35%, and the instructional load on its faculty increased by 45%.

As a result, by almost any measure, the College of Engineering finds itself today the most poorly funded unit in the University. This deterioration in support has been particularly devastating because the real costs of engineering education are high due to the extensive laboratory and computing facilities and the design and research experience demanded by quality engineering instruction.

But this simple picture does not tell the whole story. To learn the real degree of the erosion in the support of engineering education at Michigan, we must look at all components of the College's activities. Over the past year we have attempted to analyze the total operating costs and income of the College of Engineering to estimate the degree of its underfunding. This analysis includes not only direct instructional and research costs, but also indirect costs including instruction imposed on other units (e.g., engineering students taking chemistry and mathematics courses), plant maintenance and utilities, library costs, staff benefits, student financial aid and research administration, as well as both expenditures and income associated with private support.

The results of this analysis are alarming indeed. To illustrate, let me walk you through the 1981-82 budget of the College of Engineering. Below I have summarized in a simple form our budget expenditures for this year:

| | |
|---|---|
| Instruction (General Fund) | $12,513,635 |
| Research (Federal & Industrial) | 17,755,614 |
| Service (Various) | 4,928,864 |
| Indirect Costs (plant, etc.) | 4,988,478 |
| Total Expenditures | $40,186,591 |

Against these expenditures we should compare the "revenue" or recovered income generated during this period by the College:

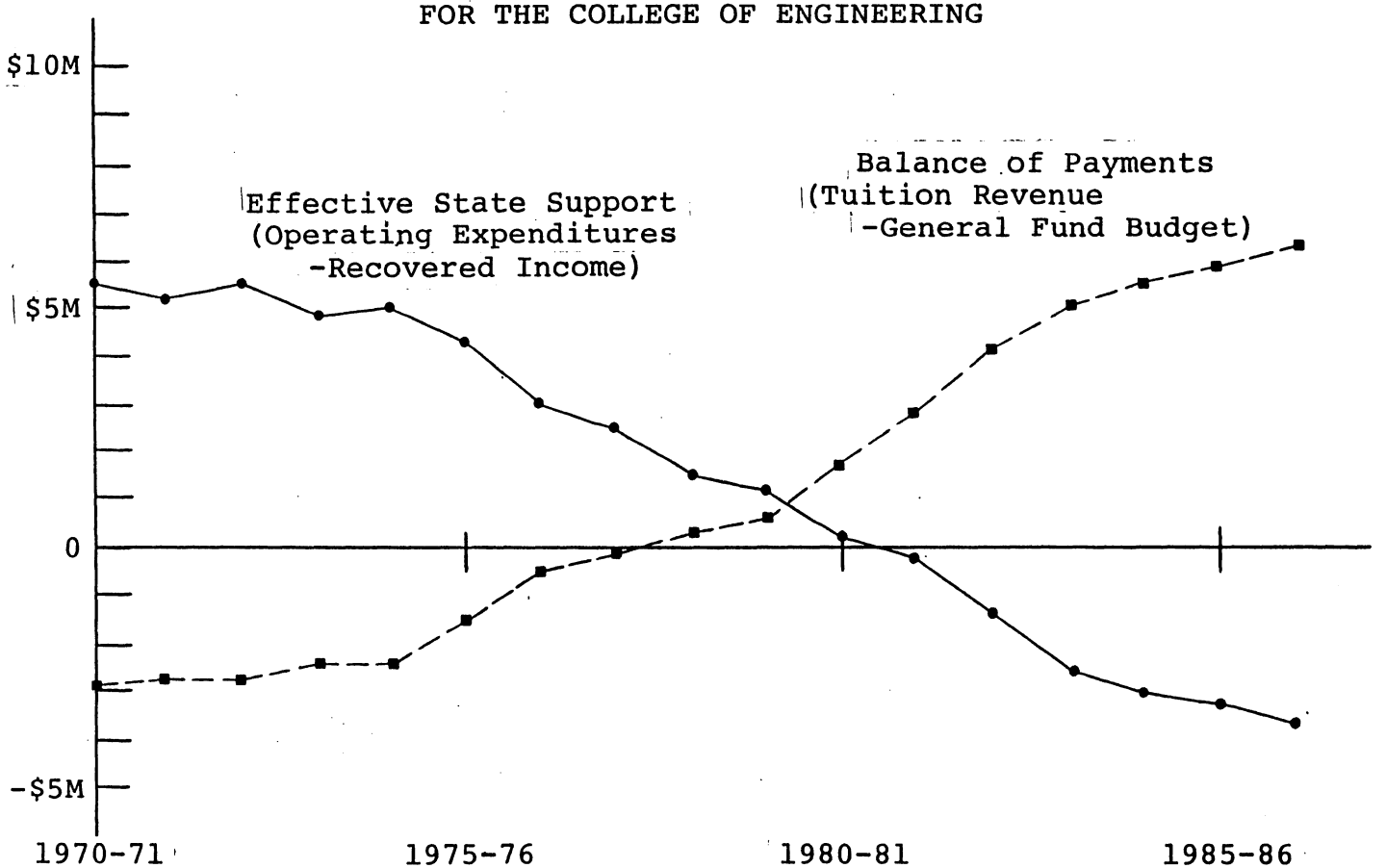
| | |
|---|---|
| Student Tuition and Fees | $15,455,826 |
| Sponsored Research (Grants) | 17,755,614 |
| Private Support | 7,102,494 |
| Total Revenue | $40,313,934 |

This financial data indicates that the true costs of the instructional and research programs of the College to the University (and therefore to the State of Michigan) were exceeded by its recovered income. That is, the effective State support received by the College dropped this year to zero. Indeed, the College generated a "profit" for the State of $127,343 — that is, it paid a sum of roughly $26 per enrolled student for the privilege of being associated with a public institution. (By way of comparison, I might note that the average State support per student enrolled at The University of Michigan is roughly $3,747 per student.) From this analysis it becomes apparent that State funding of the College of Engineering has deteriorated to the point at which it is not only the most poorly supported academic unit at The University of Michigan, but almost certainly the most poorly supported unit in any public institution in the State of Michigan. And, ironically enough, it is just this unit, the College of Engineering, that is supposed to lead this State out of its economic doldrums by revitalizing Michigan industry and attracting new, high technology industry into the State.

The impact of the past decade of underfunding on the College has been very serious indeed. We have been forced to reduce our instructional staff by 45 faculty positions during a period of substantial enrollment growth (44%) leading to a faculty that is seriously overloaded. There are strong indications that these instructional overloads have already harmed the research activities of the College. (Last year, for the first time in its history, the sponsored research volume in the College actually decreased.) Furthermore, these heavy instructional loads in the face of decreasing resources have damaged faculty morale and contributed to the loss of several outstanding faculty.

The erosion in technical support staff, equipment, and other non-salary support has seriously damaged the environment for excellence in teaching and scholarship within the College. For example, we now have electronic laboratory equipment (oscilloscopes and such) older than the students who use them. Indeed, many community colleges throughout the State have better equipped instructional laboratories than many of those in the College.

STATE SUPPORT AND BALANCE OF PAYMENTS
FOR THE COLLEGE OF ENGINEERING



At Michigan we have still a further difficulty. This is caused by the State's inability to honor its earlier commitment to match our private fund raising effort during the 1970s ($21 million) to provide the resources necessary to complete our move to a single campus. As a result, we now find our programs badly divided between two campuses. Furthermore, our largest department (Electrical and Computer Engineering) is attempting to conduct state-of-the-art engineering education in a facility that is literally crumbling around them.

Suffice it to say that a decade of deteriorating State funding during a period of major expansion in engineering enrollments has brought engineering education at Michigan to the point of collapse. Indeed, during the past decade State support of the College of Engineering has vanished entirely -- the College has become a private institution. And yet never before has the demand for graduates of the College been higher. Similarly both the quantity and quality of students applying for admission to its engineering programs are at an all-time peak. Furthermore, it has become apparent that the College is expected to play a major role in supporting State initiatives to strengthen and diversify the Michigan economy (e.g., the Industrial Technology Institute of Michigan). There is a clearly perceived national crisis in the education of advanced-degree engineers, and the College is in a unique position to become a leader in graduate education. The creative efforts of our faculty and students in research are needed both to provide the seeds for technological innovation to revitalize industry both in this State and throughout the nation.

Yet for the College of Engineering to achieve these objectives, to respond to the opportunities and meet the responsibilities that lie before it over the next decade, the College must regain a level of support commensurate with its serious needs. But where might this support come from?

It is apparent that help will not come from Washington. A number of short-sighted actions at the federal level are responsible in part for the present crisis in engineering education. During the 1970s, graduate fellowships and traineeships declined from 40,000 to less than 6,000 nationwide. Washington made a conscious effort to shift graduate student support away from fellowships to research assistantships, apparently not realizing that when indirect costs are taken into account, the effective number of students that could be supported by an equivalent amount of research dollars would be cut in half. The Reagan Administration is continuing to reduce the federal role in engineering education by terminating the National Science Foundation's science and engineering education programs and cutting support of research programs in engineering and the physical sciences. And we are all too aware of the catastrophic impact that the proposed cuts in federal student aid will have over the next several years.

Nor is higher tuition the answer. As this State has lost its will to support engineering education, we have already been forced to implement dramatic tuition increases. Indeed, at the present point in time, The University of Michigan has the "distinction" of having the highest tuition levels of any public institution in the nation ($2100 for in-state, $6500 for out-of-state students).

So where is the support (inadequate as it may be) for engineering education coming from if not from State support or tuition? It has come from the engineering faculty themselves. The acceleration in the growth of technical knowledge of the past several decades has indicated that a high quality undergraduate education in engineering cannot be separated from strong graduate education and research programs. The responsibility for generating the resources to support graduate education and research has traditionally fallen on the shoulders of the engineering faculty. In particular, their entrepreneurial efforts to attract both public and private support of their research projects and graduate students have always been a critical component of leading engineering programs such as those at Michigan.

However during the past decade declining public support has shifted more and more of the burden of our instructional program onto the backs of our faculty. As a specific example, in the College of Engineering at Michigan we now find that research grants support essentially all of our equipment purchases, graduate student support, travel, and supplies. Beyond this, roughly 35% of our faculty salaries are supported by research grants. This growing dependence of our instructional programs on research support is particularly disturbing, since it implies that more and more faculty effort is being required to write research proposals and reports, administer research contracts, and carry out all of the other "non-scholarly" activities associated with hustling research support — just to maintain the quality of our instructional programs (not to mention our research programs).

To place this in perspective, we estimate it costs roughly $7,500 per student per year for an engineering education at The University of Michigan. At the present time the student pays some $2000 if in-state ($6500 if out-of-state). As I have indicated, State support has now eroded away to zero. Hence the remainder of this cost, some $5,500 or 75% of the cost of educating our students, is now being borne by a combination of sponsored research grants, contracts, and private support.

This precarious situation cannot — and, indeed, will not — continue. We simple cannot maintain the quality of our instructional and research programs that have made the College of Engineering a national leader without a major change in our level of support.

Parenthetically, I would note the contrast with the Sunbelt, in which there has been a growing awareness of the importance of quality institutions of higher education in the attraction of new industry — and the commitment of public support compatible with this recognition. One need only look at the growth in public funding of engineering institutions in Arizona, Texas, Florida, Louisiana, and so on to find vivid examples of strong public support that stand in sharp contrast with those found in Michigan.

Speaking as a professor (and not just as a dean), I must note the irony in this decline in public support of engineering education in Michigan. For just when we should be recognizing the importance that engineering will play in rebuilding the competitiveness of industry within this State (and the nation), we are proceeding to cut public support of this enterprise. We are dismantling the most distinguished of our engineering schools. And yet these are just the institutions that will (or at least should) play the key role in

should) play the key role in rebuilding the industrial productivity both in Michigan as well as in the rest of the nation while preserving our national security.

## 6. THE SOLUTION

So what is to be done? How can this State's engineering programs respond to such a devastating erosion in public support? Let me begin by describing the response at Michigan and then offer several suggestions for more general action.

### 6.1 The Michigan Response

Despite this deterioration in the support of engineering education which has occurred over the last decade, I assure you that the College of Engineering at The University of Michigan is committed to the achievement of excellence in education, research, and in the professional activities of our faculty, students, and graduates that have made us a national leader. We fully intend to continue this tradition of excellence. We intend to be the best — and nothing less will do.

But the parameters have changed dramatically. In the face of a continuing decline in public support, we are taking prompt and strong actions to maintain our commitment to excellence in engineering education. Our general philosophy is quite simple:

i) We must keep as our primary objective the achievement of excellence in our instructional and research programs.

ii) We must strive to maintain the flexibility to respond to changing needs and priorities.

iii) We must be prepared to shift resources when necessary, possibly reducing or even eliminating some programs and activities in order to improve or initiate others. In such decisions we will stress the important criteria of quality, centrality to our mission, and cost-effectiveness.

More precisely, if we are to achieve excellence in the face of the present economic difficulties confronting us, we believe it essential to carefully select only a few new areas of major thrust and target our available resources at these. While it is certainly true that the College of Engineering at Michigan has traditionally been distinguished by its breadth, this was achieved during a time of dramatically different funding parameters. We refuse to accept the premise that we should attempt to do simply an adequate job across the board. We are committed to being the best in certain key areas, and we will focus our resources accordingly.

The College is now developing administrative structures and policies to facilitate reviews and resource reallocation so that programs that fail to meet the tests of centrality, quality, and cost-effectiveness can be reduced or eliminated to provide the resources necessary to strengthen existing

programs or to initiate new programs of high priority . Over the course of the next two years, essentially all academic, service, and administrative units of the College will be reviewed to evaluate their potential for excellence.

In a sense, we are approaching our future as if we were seated at the table of a very high stakes poker game. We will place our bets both carefully and courageously. That is, we will choose key areas in which we think we have the capacity to be the best — and then we will push out all of our chips into the center of the table — we will make the total commitment necessary to achieve world leadership.

6.2. The Role of Industry

From our present (though hopefully temporary) vantage point as a "private institution," we have carefully analyzed the possibility of replacing dwindling sources of public funds with increased support from the private sector. Fortunately, the alumni of the College have demonstrated strong loyalty and generosity in the past, and we will become even more dependent on this strong support in the future.

We believe, however, that an important element in addressing the crisis in engineering education will be a major change in attitude and commitment on the part of private industry. Industry must move rapidly to accept a far more signficant role in the support of engineering education.

Let me be more specific. We now estimate the cost of an engineering education at Michigan at roughly $50,000 ($7,500 instructional cost plus $5,000 for room, board, books, travel, etc., each year). At Michigan this past year we graduated roughly 1,000 undergraduates, most of whom took jobs in industry. In a sense we provided industry with some $50,000,000 worth of engineering manpower. And this was provided essentially free of charge (since we no longer benefit from State support and hence from the taxes paid by private industry). However it is obvious that this situation cannot — and indeed, will not — continue. The public is no longer supporting engineering education; the student can no longer afford the staggering tuition levels; and the faculty has become so overburdened that they can no longer be expected to generate the research support to carry the cost of our instructional programs.

Industry must move rapidly to provide major financial support of engineering education. Indeed, without such support their supply of engineering manpower stands in serious jeopardy, and one by one the leading engineering schools will be forced to implement massive enrollment cuts.

But here engineering colleges must do their share. We must approach industry with a willingness to respond to its needs, and in so doing, develop relationships that will lead to direct support of engineering education by industrial sponsors. We must EARN the support of industry.

All too often both sides of this important partnership have taken the other for granted. For the past two decades engineering colleges have been distracted by the lure of federal research support to the neglect of their relationships — indeed, their obligations to — private industry.

By the same token most industries still do not realize their very strong obligations and vested interests in maintaining a healthy engineering education system. They continue to ignore the pleas of colleges for assistance while luring away their faculty with more lucrative industrial opportunities — in effect, cannibalizing their own future supply of engineering manpower. In fact, industrial support of engineering education is at a lower relative level than it was in 1960 during a period of strong federal support.

When requests are made for the support of engineering education, one frequently hears the response from industry: "We support education through the taxes we pay — not through direct contributions!" Well, years ago this may well have been the case. But in recent years, more and more of these tax dollars have gone to support social services and other public needs — and less and less have gone to the support of higher education. In the case of the College of Engineering at The University of Michigan this has been carried to an extreme as public support has effectively vanished.

Indeed, several companies are now attempting to bypass America's colleges and universities by developing their own internal engineering education programs — even schools. For example, it is estimated at the present time that business and industry allocate more than $30 billion a year to education and training, almost as much as the annual expenditure on all of this nation's publicly financed colleges and universities.

Certainly industry has the resources to assist engineering education in a major way, if we can demonstrate that this support is in industry's best interests — and if industry will change its traditional attitudes toward such direct and massive support.

### 6.3 A New Partnership

We believe that the College of Engineering at The University of Michigan represents a valuable resource that can play a major role in revitalizing and diversifying industry both in Michigan and throughout the nation through the creative activities of its faculty and the quality and ability of its engineering graduates. As a public institution, the College believes it has a major responsibility to respond to the needs of this State and the needs of Michigan industry.

I assure you that the College of Engineering intends to do its best to meet its responsibility. We have undertaken new initiatives to refocus our efforts to meet the particular needs of industry. The recent establishment of the Center for Robotics and Integrated Manufacturing, the Computer-Aided Engineering Laboratory, our Industrial Affiliates programs, and our Continuing Engineering Education and Co-operative Engineering Education programs are all examples of the sincerity and extent of this commitment on the part of the College.

Yet, no matter how committed we may be to assisting in this critical task, it is also clear that without a comparable commitment from State government and industry, we will simply not have the capacity to fulfill our responsibilities. Engineering education in this State is at a critical juncture. A decade of neglect has brought it to the brink of collapse. We simply cannot maintain the level of excellence needed to fulfill the important

mission required of us in the revitalization of Michigan as long as we continue to struggle with inadequate funding, decaying physical facilities, obsolete equipment, and a seriously overloaded faculty.

The handwriting on the wall could not be clearer. Universities, industry, and State government all must make a renewed commitment to working together to revitalize this State. Speaking for the College of Engineering at The University of Michigan, I assure you that we have made a strong commitment to the future of this State. We have signed our part of the agreement, and we have the will and determination to play the major role expected of us — if we have the capacity.

I also believe that our partners, State government and industry, have the capacity to join with us in revitalizing Michigan. Only one question remains. Do they have the foresight and the will to make similar commitments? For without such immediate and major commitments they will complete the dismantling of one of this State's greatest assests, its leading institution of engineering education and research.

That, I suppose, is the challenge. Do State government and industry have the will and the foresight to respond now, to join us in a partnership to rebuild Michigan? Or will they simply sit back and watch, waiting in vain for others to assume the responsibility for the support of this enterprise, while one of the truly great institutions of engineering education in this nation decays into mediocrity through neglect.

DATA SUMMARY
FOR THE COLLEGE OF ENGINEERING

1. STUDENTS

| | | | |
|---|---|---|---|
| Enrollment (Fall-81) | 4,360 | Undergraduates | (19% women, 5% minority) |
| | 774 | M.S. | |
| | 361 | Ph.D. | |
| | 5,495 | | (growth of 48% since 1975) |
| Degrees Conferred (1980-81) | 997 | B.S. | (up by 50% since 1975) |
| | 464 | M.S. | |
| | 54 | Ph.D. | |
| | 1,515 | | |

Student Quality: SAT: 1200; 23% in 99%; 78% in 90%

(In 1980-81 a typical B.S. graduate received 5 job offers at $25 -$26 K. 1981-82 —> $28-$30 K)

2. FACULTY

| | | 80-81 | 81-82 |
|---|---|---|---|
| Staff Size: (Head count) | Professors | 161 | 163 |
| | Associate Professors | 42 | 50 |
| | Assistant Professors | 48 | 45 |
| | Faculty | 251 | 258 |

Age Distribution:

| | |
|---|---|
| 25-39: | 69 |
| 40-49: | 66 |
| 50-59: | 79 |
| 60-69: | 46 |

(Projected retirements during 1980s: Definite: 54; Probable: 90)

| | | 80-81 | 81-82 |
|---|---|---|---|
| Salary Averages: (Acad. Yr.) | Assistant Professors: | $22,536 | $29,400 |
| | Associate Professors: | 27,115 | 31,900 |
| | Professors: | 37,424 | 42,100 |

(Typical appointment: Academic year: 80% General Fund, 20% Sponsored Research; Summer: 100% Sponsored Research)

3. QUALITY:

Michigan is generally ranked 5th nationally behind M.I.T., Stanford, U.C. Berkeley, and Illinois. Of its 19 degree programs, 13 are ranked among the top five in the nation, and 9 rank first among all public universities.

4. BUDGET

1981-82 Operating Budget Expenditures

| | |
|---|---|
| General Fund Budgeted Expenditures | $12,513,635 |
| Sponsored Research | 12,453,727 |
| Indirect Costs (instruction & research) | 10,238,865 |
| Private Support and Services | 4,980,364 |
| | $40,186,591 |

1981-82 Operating Budget Revenue

| | |
|---|---|
| Student Tuition and Fees | $15,455,826 |
| Research (Direct Costs) | 12,453,727 |
| Research (Indirect Costs) | 5,301,887 |
| Service and Private Gifts | 7,102,494 |
| | $40,313,934 |

Net Operating Cost to University for 1981-82: -$127,343

Net Operating Cost per Enrolled Student: -$23 per student-year

5. PHYSICAL FACILITIES

Present:

| | | |
|---|---|---|
| Central Campus: | West Engineering | (Civil, IOE, ME, Admin) |
| | East Engineering | (ECE, Humanities, ChE, MME, ME) |
| | UGLI | Engineering/Transportation Library |
| North Campus: | Aero | Aero |
| | Space Physics | A&OS |
| | Cooley | Nuclear (+ ECE labs) |
| | Naval Arch. | NAME |
| | GGBL-Auto Lab | labs of ME, Civil, Chem E |

Future:

| | | |
|---|---|---|
| Central Campus: | West Engineering | Towing Tank |
| North Campus: | Aero | Aero |
| | Space Physics | A&OS |
| | Cooley | Nuclear |
| | Naval Arch. | NAME |
| | Dow (6/1/82) | ChE, MME |
| | GGBL-Auto (82) | ME, Civil |
| | Res Ad (82) | IOE |
| | Engineering Building I (84) | ECE, Admin |

# 1980 GORMAN RANKINGS OF ENGINEERING PROGRAMS

| | U.G. | GRAD |
|---|---|---|
| AEROSPACE | MIT | MIT |
| | Michigan | Caltech |
| | Princeton | Michigan |
| | Minnesota | Princeton |
| | Illinois | Stanford |
| | Stanford | Cornell |
| | Brown | Illinois |
| | Ohio State | Purdue |
| | Iowa State | Minnesota |
| | Kansas | Georgia Tech |
| CIVIL | Cal-Berkeley | Cal-Berkeley |
| | Illinois | Illinois |
| | MIT | MIT |
| | Stanford | Stanford |
| | Cornell | Cornell |
| | Purdue | Caltech |
| | Michigan | Purdue |
| | Columbia | Michigan |
| | Northwestern | Columbia |
| | Carnegie | Wisconsin |
| INDUSTRIAL | Stanford | Michigan |
| | Michigan | Cal-Berkeley |
| | Cal-Berkeley | Stanford |
| | Purdue | Purdue |
| | Northwestern | Wisconsin |
| | Georgia Tech | Cornell |
| | Cornell | Georgia Tech |
| | Ohio State | Northwestern |
| | Columbia | Columbia |
| | Texas A&M | Ohio State |
| METALLURGICAL | Illinois | Illinois |
| | Colorado | Columbia |
| | Missouri | Pittsburgh |
| | Columbia | MIT |
| | Minnesota | Carnegie |
| | Penn State | Colorado |
| | Carnegie | Penn |
| | Case | Minnesota |
| | Michigan | Michigan |
| | Ohio State | Lehigh |
| NAVAL (U.G. only) | MIT | |
| | Michigan | |
| | Webb Institute | |
| ENG SCI (U.G. only) | Caltech | |
| | Harvard | |
| | Michigan | |
| | Georgia Tech | |
| | Penn State | |
| | Iowa State | |
| | Yale | |

| | U.G. | GRAD |
|---|---|---|
| CHEMICAL | Princeton | Wisconsin |
| | Wisconsin | Princeton |
| | Cal-Berkeley | Cal-Berkeley |
| | Minnesota | Minnesota |
| | MIT | MIT |
| | Stanford | Illinois |
| | Illinois | Stanford |
| | Caltech | Caltech |
| | Michigan | Michigan |
| | Delaware | Delaware |
| ELECTRICAL | MIT | MIT |
| | Stanford | Cal-Berkeley |
| | Cal-Berkeley | Stanford |
| | Illinois | Illinois |
| | Michigan | Michigan |
| | Princeton | Princeton |
| | Purdue | Caltech |
| | Cornell | Purdue |
| | Minnesota | Cornell |
| | Wisconsin | UCLA |
| MECHANICAL | MIT | MIT |
| | Stanford | Stanford |
| | Cal-Berkeley | Cal-Berkeley |
| | Michigan | Caltech |
| | Brown | Michigan |
| | Minnesota | Minnesota |
| | Illinois | Illinois |
| | Purdue | Purdue |
| | Cornell | Princeton |
| | Princeton | UCLA |
| NUCLEAR | Columbia | MIT |
| | Michigan | Michigan |
| | Wisconsin | Wisconsin |
| | Virginia | Cal-Berkeley |
| | Penn State | Georgia Tech |
| | RPI | Virginia |
| | Texas A&M | Columbia |
| | Arizona | Illinois |
| | Illinois | RPI |
| | Cal-Berkeley | Texas A&M |
| MATERIALS (U.G. only) | Cornell | |
| | Northwestern | |
| | Michigan | |
| | Cal-Berkeley | |
| | MIT | |
| | Brown | |
| | RPI | |
| | Vanderbilt | |
| | Case | |
| | Carnegie | |
| ENVIRONMENTAL (U.G. only) | Caltech | |
| | Harvard | |
| | Michigan | |
| | Northwestern | |
| | Penn State | |
| | RPI | |
| | Texas | |
| | Florida | |