



COLLEGE OF ENGINEERING  
THE UNIVERSITY OF MICHIGAN  
ANN ARBOR, MICHIGAN

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**A PROPOSAL TO THE  
MICHIGAN RESEARCH  
EXCELLENCE FUND  
TO ESTABLISH A  
CENTER OF SCHOLARLY  
EXCELLENCE IN  
MACHINE INTELLIGENCE  
TECHNOLOGY**

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## ABSTRACT

The convergence of computer, communication, and control technology induced by microelectronics, together with advances in software engineering and the application of artificial intelligence is leading to a new field of application known as machine intelligence. Leaders in manufacturing technology are now viewing machine intelligence as central to the control of manufacturing processes for greater productivity and higher quality. As the "eyes and brain" of robotics and other assembly and processing machines, it is a major component of the complex technology of the future. Machine intelligence is also central to the development of autonomous vehicles and is also beginning to augment management decision making and procedures. The consensus of the most leaders from the automobile industry, computer and automation industry, and research and development institutions, is that the economic impact of machine intelligence will greatly exceed that of the more limited field of robotics.

The University of Michigan College of Engineering seeks base funding at a level of \$3,500,000 per year from the Michigan Research Excellence Fund to establish and sustain a center of scholarly excellence in machine intelligence. This thrust is well-aligned to Michigan's objective of becoming the nation's source of emerging industrial technology, since there is good reason to believe that both the principal producers and consumers of machine intelligence technology will be located in the Great Lakes area.

UM Engineering has already been working closely with key Michigan companies (including Electronic Data Systems and the General Motors Technical Center) in building strong programs in this critical area. More recently, the College is assisting the Engineering Society of Detroit in creating the first national Society of Machine Intelligence.

With sustained support from the Research Excellence Fund, the University of Michigan believes it can build on this momentum to establish the nation's leading academic center of research in machine intelligence. Such an investment would be an important step in assuring that this new industry, so critical to complex manufacturing activities, takes root and flourishes in the State of Michigan.

## 1. AN INVESTMENT IN ENGINEERING EXCELLENCE

There is strong evidence to suggest that a primary catalyst and necessary ingredient in technology-based industrial development is the presence of a world-class engineering school. Such institutions provide not only the outstanding engineering graduates necessary to sustain and strengthen the competitiveness of existing industry; in addition, they supply the technological innovation and entrepreneurs necessary for building new industry.

The presence in the State of Michigan of one of the nation's leading engineering schools, the University of Michigan College of Engineering, is of critical importance of its future economic prosperity. Michigan requires a massive infusion of new technology if it is to regain its traditional industrial and economic leadership and become the nation's source of emerging industrial technology, the world's leader in complex manufacturing processes. Our state must use technology to revitalize and diversify its present industrial base to protect existing jobs, even as it seeks to spawn and attract new industries over the longer term to create new jobs for Michigan citizens.

The dominant role played by world-class engineering schools in economic development has been identified in study after study. In California and New England, most of the significant technological innovations behind industrial growth originated in key local engineering schools and their associated research laboratories (e.g., MIT, Stanford, UC-Berkeley, and Caltech). These innovations were typically exploited by new firms established by faculty, staff, and graduates of these schools. Companies with origins in these schools subsequently formed the basis of powerful agglomerations of new industries. Furthermore, these schools attracted the massive federal research contracts which played the key role of "risk capital" in building new industries such as electronics and aerospace.

In each case, the key engineering schools involved were top-flight institutions conducting research at the cutting edge of new technology. Furthermore, these schools were oriented to the commercial applications of their innovations, provided the entrepreneurial environment necessary for technology transfer, and attracted the federal funding necessary to stimulate such industrial development.

It is reasonable to expect that the role of a world-class engineering school will be even more critical in a future increasingly dominated by science, technology, and information. There seems little doubt that Michigan's ability to strengthen and diversify its industrial base, to compete for new industry and economic growth, and to create the jobs necessary for Michigan's long-term prosperity will depend on its success in building and sustaining such an institution.

The University of Michigan College of Engineering provides

Michigan with both a vehicle and an extraordinary opportunity for investing in the long-term economic health of the state. As one of the leading engineering schools in the nation today, the College is regarded as one of the few institutions in the world capable of achieving the degree of excellence in science and technology necessary to have a major impact on economic development.

More specifically, the present status of the UM College of Engineering can be summarized as follows:

Reputation: 5th in the nation  
Capacity: 6,000 students, 320 faculty (3rd in the nation)  
Productivity: 1,250 BS, 550 MS, 100 PhD degrees annually  
Research: \$25 million per year (federal and industrial)  
Student Quality: 98th percentile (1280 SATs, 3.8 GPAs)  
Faculty Quality: Outstanding (energetic and innovative)  
Physical Plant: Rapidly improving  
Laboratory Equipment: Seriously deficient  
Base Funding: Seriously deficient

Over the years, UM Engineering has had a major impact on Michigan's economic prosperity:

- o Each year the College graduates over 1,800 engineers, of whom roughly 70% remain in the Great Lakes area.
- o UM Engineering has been recognized as a national center of excellence in several areas of importance to Michigan, such as complex manufacturing technology, ergonomics, advanced electronics and optics, and computer engineering.
- o The College has formed important research partnerships with Michigan companies across a broad range of technologies.
- o Over the past three decades, the College and its affiliated research laboratories have spawned over 85 companies employing 40,000 Michigan citizens and generating over \$2 billion per year in sales.
- o UM Engineering faculty and staff are accelerating the rate at which they spin off new companies (7 in 1984).

The UM College of Engineering today is in an excellent position to achieve national leadership in areas of major importance to Michigan's future including complex manufacturing technology, advanced electronics and optics technology, and machine intelligence and information technology. However, if the College is to have the capacity to respond to such needs and opportunities, it will require direct and immediate assistance from the State of Michigan to restore an adequate base level of support for its programs through initiatives such as the Research Excellence Fund.

## 2. THE IMPORTANCE OF MACHINE INTELLIGENCE TO MICHIGAN

Numerous studies have suggested that Michigan's economy will continue to be driven for the foreseeable future by durable goods manufacturing. However it is essential that this industry shift rapidly to complex manufacturing processes less vulnerable to low-wage competition. Michigan's future economic prosperity will depend on its becoming America's "factory of the future", its leading source of emerging industrial technology. In contrast to other regions of the country in which "high tech industries" are regarded as a separate industrial sector, in Michigan new technology will be at the heart of every industrial sector.

However, there is another equally important aspect of technology-based economic development for our state. Experience has shown that a primary source of new jobs is the creation of new companies and industries. And while durable goods manufacturing will continue to provide the basis of this state's economy in the near term, it is essential that Michigan stimulate and nurture the growth of new industries that will diversify and strength its economy for the long term. It is logical to expect that advanced technology and innovation will play the key role in bulding these new companies and creating new jobs.

In summary, then, Michigan faces two major challenges: First, our state must take actions to protect its present economic base by strengthening the competitiveness of existing industries such as the automobile and automotive supplier industry. Second, it must establish an environment capable of attracting or stimulating the growth of technology-based industries that can provide new jobs for Michigan citizens. Key in both efforts will be the availability of centers of excellence and innovation in key areas of technology.

Numerous State of Michigan studies have singled out the unique role of the UM College of Engineering in this effort. For example, one of the key recommendations of the Governor's Task Force for a Long-Term Economic Strategy for Michigan was:

"To ensure the lead propositon in the development of manufacturing production processes, Michigan must invest heavily in centers of applied research in industrial technology, with special emphasis on developing the University of Michigan College of Engineering as a world leader in this field."

One of the key areas in which such investments must occur is the important new area of machine intelligence.

### 2.1. Machine Intelligence

The convergence of computer, communication, and control technology induced by microelectronics, together with advances in software engineering and the application of artificial

intelligence is leading to a new field of application known as machine intelligence. Indeed, many knowledgeable engineers and scientists now refer to this technology as "robotics - phase II".

Intelligent systems are characterized by:

- o real-time input from the environment, including vision
- o storage and retrieval of knowledge about a portion of the real world
- o decision based upon incomplete, unstructured information
- o self-modification and improvement of decision-making capabilities
- o influence of the environment through control of actuators, machines, and mechanical systems.

Leaders in manufacturing technology are now viewing machine intelligence as central to the control of manufacturing processes for greater productivity and higher quality. As the "eyes and brain" of robotics and other assembly and processing machines, machine intelligence is a major component of the complex manufacturing technology of the factory of the future. This technology is also central to the development of autonomous vehicles and is beginning to augment management decision making and procedures. Other phases associated with the field of machine intelligence include machine vision, expert (rule-based) systems, and knowledge engineering.

It now seems apparent that leadership in this important new technology will be essential to the achievement of Michigan's objective of becoming the nation's source of emerging industrial technology. Fortunately, there is already good reason to believe that our State has an important advantage in becoming the world leader in machine intelligence.

- o The first important phase of machine intelligence involves the development and implementation of machine vision systems. Due to the strong technological base provided by laboratories such as the General Motors Technical Center, the Environmental Research Institute of Michigan, and the UM College of Engineering, there has already been an explosion in the formation of machine vision companies in Michigan.
- o The leading consumers of such technology will be durable-goods manufacturing industries such as the automobile industry. Indeed, machine intelligence technology will be critical to major new efforts such as the General Motors Saturn Project.
- o The first national Society of Machine Intelligence is being formed by engineers and scientists in Michigan.

## 2.2. The Role of the UM College of Engineering

The University of Michigan College of Engineering is playing a key role in the development of this important new technology. Of course, key laboratories of the College and their derivatives have spawned much of the machine vision industry now building in Michigan. However, beyond that, UM Engineering has worked closely with Michigan industry to develop important research partnerships in machine vision technology, including a massive research program with the Advanced Product and Manufacturing Engineering Staff of the General Motors Technical Center. It has also recently begun an important new relationship with EDS in the related area of knowledge engineering.

More recently, UM Engineering has worked closely with the Engineering Society of Detroit to create the first national Society of Machine Intelligence. This Society will soon conduct both a top-down and bottom-up (Delphi) study to assess the economic impact of machine intelligence technology.

UM Engineering has taken strong steps to build its capacity for national leadership in this key technology. It has recently added several new faculty with strong credentials in the area of artificial intelligence. Furthermore, early in 1985 Lynn Conway, formerly Chief Scientist of the Xerox Palo Alto Research Center and head of the Department of Defense Strategic Computing Initiative, joined the College as a Professor and Associate Dean with the mission of leading this effort.

The College is also playing an important role in transferring this important technology. Working closely with the Industrial Technology Institute, it is developing education and training programs in machine intelligence for engineers and skilled trades of General Motors. Furthermore, UM Engineering has begun to work closely with organized labor (UAW and AFL-CIO) to provide assistance in technology assessment and educational needs assessment.

## 3. SPECIFIC PROPOSAL

The achievement of a national Center of Excellence in Research on Machine Intelligence at the University of Michigan will require a sustained base commitment from the State of Michigan of \$3.5 million per year. Of this amount, \$1,500,000 will be necessary to attract and support the faculty necessary to staff and direct these research programs. In addition, a base commitment of \$2,000,000 per year is necessary to leverage the massive industrial and federal contracts, contracts, and gifts necessary to equip such laboratory facilities. Detailed budget requests for staffing and equipment are provided in Tables I, II, and III.



Fortunately several of the most critical components necessary for the establishment of the Center are already in place:

- o The University of Michigan already conducts programs in computer science and computer engineering that are within striking distance of national leadership.
- o The University has recently completed a major reorganization of these programs into a new "super" Department of Electrical Engineering and Computer Science which spans activities ranging from microelectronics to computer science and engineering to systems engineering. This unusual action will make the University of Michigan one of only a handful of institutions in the nation able to coordinate research and instructional programs in computer technology, thereby providing it with instant visibility and credibility in attracting new faculty of the quality necessary for national leadership.
- o These programs presently attract perhaps the largest concentration of high quality students in the country. This year the degree programs offered by the Department of Electrical Engineering and Computer Science enroll over 1,800 students drawn from the 99th percentile of high school graduates.
- o The presence of the Center for Research in Integrated Manufacturing and the Industrial Technology Institute provide a strong infrastructure for research in interdisciplinary areas such as machine intelligence.

There is strong reason to believe that Michigan stands on the threshold of achieving world-class capabilities in machine intelligence technology -- if the State is prepared to make the investments in sustained funding necessary for the support of such activities.

### 3.1. Laboratory Equipment

It is important to understand that research programs in machine intelligence and related technologies are equipment-intensive. Of particular importance are state-of-the-art computer facilities.

Fortunately, UM Engineering is well along in its efforts to build the necessary computing environment through its development of the Computer Aided Engineering Network (CAEN). CAEN consists of a distributed-intelligence, hierarchical computing system linking together microcomputer workstations, superminicomputers, mainframe computers, function-specific machines, and gateway machines to supercomputer installations and external networks. The system now supports not only traditional engineering research and instruction, but as well a broad array of administrative

services.

A significant fraction of the sustained funding requested for equipment will be utilized to support the research component of CAEN directly applicable to machine intelligence activities.

### 3.2. Staffing

The detailed staffing needs for the Center are listed in Table III. The primary investment will be in the additional faculty necessary to build a critical mass for the research programs. Also included is the necessary expansion of technical support staff and research assistants.

TABLE I  
BASE BUDGET NEEDS  
CENTER FOR RESEARCH ON MACHINE INTELLIGENCE

Staffing

Faculty participants: 22 FTEs	\$1,800,000
Technical support staff: 10 FTEs	300,000
Graduate research assistants: 16 FTEs	400,000
Laboratory equipment (sustained needs)	1,000,000
Total Base Budget Needs	\$3,500,000

TABLE III  
LABORATORY EQUIPMENT NEEDS

ITEMS	UNIT	FAC	STF	STU	TOTAL	TOTAL &
<b>Workstations</b>						
Basic mono	10,000.00	200	200	500	900	9,000,000.00
Basic color	40,000.00	25		100	125	5,000,000.00
Hi per mono	45,000.00	50		100	150	6,750,000.00
Hi per color	70,000.00	25		50	75	5,250,000.00
Comp. Nodes	35,000.00	10		25	35	1,225,000.00
Total wrkstat.					1250	
PC/terminal	1,200.00		100		100	12,000.00
Sub-t						<u>\$27,345,000.00</u>
<b>File servers</b>						
Node adapters	7,000.00	28	25	75	128	896,875.00
300 MB	15,000.00	56	50	150	256	3,843,750.00
158 MB	15,000.00	85	0	175	260	3,900,000.00
Tape	12,000.00	15	15	15	45	540,000.00
Sub-total						<u>\$ 9,180,625.00</u>
<b>Print servers</b>						
Laser print	25,000.00				105	2,625,000.00
Color printer	35,000.00				10	350,000.00
LQ matrix	6,000.00				0	0.00
Sub-total						<u>\$ 2,975,000.00</u>
<b>Backbone</b>						
Interface	2,000.00				15	30,000.00
Cable	500,000.00				1	500,000.00
Sub-total						<u>\$ 530,000.00</u>
<b>Software</b>						
Core Site	100,000.00				1	100,000.00
Application	800,000.00				1	800,000.00
Sub-total						<u>\$ 900,000.00</u>
<b>Grand Total</b>						<u>\$40,930,625.00</u>

TABLE III  
STAFFING REQUESTS

Faculty Participants		22 FTEs
Machine Intelligence		
Robotics	2	
Machine Vision	3	
Electronic materials	2	
Applied Artificial Intelligence		
Expert Systems	3	
Artificial Intelligence	2	
Computer Science and Engineering		
Software Engineering	4	
Operating Systems	2	
Computer Architecture	4	
Technical Support Staff		4 FTEs
Graduate Research Assistants		12 FTEs

#### 4. CONCLUDING REMARKS

There is ample evidence across this nation to demonstrate the impact that world-class engineering schools have on economic development. A major investment by the State of Michigan in the UM College of Engineering through the Research Excellence Fund can be expected to have a similar impact on our State's long-term economic prosperity. Furthermore, since the most talented of Michigan's high school graduates now enroll in the College, such action would also represent an important investment in Michigan's most valuable resource, its youth. These extraordinarily talented students will become the leaders and bulders of Michigan industry. Not only will they sustain the competitiveness of existing Michigan companies, but they will found the new companeis necessary to diversify Michigan's economic base.

The UM College of Engineering is unique in this State in its ability to attract outstanding faculty and students necessary to achieve national leaderhsip. Furthermore, it alone possesses the reputation to leverage this investment of State support several-fold through federal and industrial grants and contracts.

The requested investment of \$3.5 million in base support of a Center of Research in Machine Intelligence is modest compared to the almost certain economic impact of such activities.

Roughly 70 years ago, the automobile industry originated in the inspired inventions of self-educated craftsmen skilled in building engines for boats and machinery. The industry took root in Michigan and triggered the economic growth which led to the impressive social institutions characterizing our State today. However, recent patterns of economic development such as Silicon Valley and Route 128 suggest that future industrial growth will be stimulated less by physical capital than by intellectual capital -- by technological nnovation, the talented engineers capable of understanding and applying this technology, and the entrepreneurs capable of stimulating industrial growth.

Leading engineering schools such as the UM College of Engineering are the key sources of these essential ingredients for technology-based economic development. It is from this perspective that research programs of the UM College of Engineering such as the Center for Research on Machine Intelligence must be viewed as one of the most important investments Michigan can make for its long-term economic prosperity.

## APPENDIX A

### THE IMPORTANCE OF NECESSARY "INFRASTRUCTURE" SUPPORT

While the support of research "Centers of Scholarly Excellence" are of major importance to Michigan's future, it is essential to recognize that such Centers will only be successful if the State restores a adequate level of base funding to sustain the "infrastructure" of the parent academic unit. Perhaps nowhere is this more apparent than in the crisis presently faced by the University of Michigan College of Engineering.

The importance of world-class engineering programs to economic development has been recognized by state after state. One by one, states such as Illinois, Ohio, Pennsylvania, Minnesota, Indiana, and New York have made massive commitments to build the MITs, the Berkeleys, and the Stanfords of tomorrow. They have recognized that only nationally competitive engineering schools are capable of a major impact on economic development, since only such world-class programs are able to attract the outstanding faculty, the students, and the economic and technological resources necessary to stimulate the growth of new industry.

But, Michigan, unlike most of these other states, already has an institution with a competitive edge, the UM College of Engineering. Ironically, our state also stands apart from others in its failure thus far to restore an adequate level of support to its premier engineering school. During a decade in which enrollment in the College grew by over 45% to its present level of 6,000 students, the level of state funding for its programs has dropped dramatically. The College is currently understaffed by at least a factor of two relative to state formula funding models. This has led to a seriously overloaded faculty and limited opportunities for research and spinoff activities. Furthermore, technical support staff and equipment funds were cannibalized to offset the deterioration in state support, and this has resulted in obsolete and inadequate laboratories and an equipment and computer inventory backlog now estimated at over \$70 million.

Despite its importance to Michigan, the College's capacity to respond to the needs of Michigan and its citizens has been seriously crippled by inadequate state support. More serious is the probable consequence that over the next several years the College will be forced to cut enrollments by as much as 50% and dismantle programs of critical importance to this state if this chronic underfunding cannot be reversed.

To calibrate the magnitude of this underfunding, it should be noted that the UM Engineering College receives an annual instructional budget of roughly \$3,900 per student, compared to levels of \$5,500 in most public peer institutions (Illinois, Purdue, Wisconsin,...) and an increasing number of emerging institutions (Texas, Arizona, Florida, Maryland,...). In sharp contrast, the leading engineering institutions such as UC-Berkeley,

MIT, and Stanford receive roughly \$7,000 per student for their instructional programs -- twice that provided to UM Engineering. It is evident that unless this serious funding gap is erased, the UM Engineering College will find it increasingly difficult to compete for the faculty and other resources necessary to achieve the national leadership required for maximum economic impact.

If the University of Michigan College of Engineering is to have the capacity to participate in positioning Michigan as the leader in merging industrial technology, it will require direct and immediate assistance from the State of Michigan to restore an adequate base level of support for its programs. University officials, working closely with leaders from State government, business, labor, and industry, have developed the following two-stage plan for special action:

State I (the "restoration" phase) of this plan would involve the rapid restoration of a level of State support for UM Engineering comparable to that presently received by other peer and emerging public institutions. Since UM Engineering's level of General Fund support per student (\$3,900) presently falls \$1,600 behind these institutions, such action will require a base budget increase of \$8.5 million (allocated both to staffing and sustained equipment support). Additional one-time support of \$20 million will be required to support major initiatives in the critical areas of complex manufacturing technology, advanced electronics and optical devices, and advanced materials.

In Stage II (the "leadership" phase), a sequence of State investments would bring the support of UM Engineering to a level comparable to that of leading engineering schools (e.g., UC-Berkeley, MIT, Stanford, UCLA). This will require an additional increase in base appropriations of \$9.5 million (bringing the General Fund support per student to \$7,000) and one-time equipment support of an additional \$20 million to restore the College's laboratory equipment inventory to competitive levels. In addition, two new physical facilities would be required: a \$20 million building to house laboratories for rapidly changing areas of technology, and a \$20 million facility to serve as an incubation center for bringing together startup companies and satellite corporate R&D laboratories with College faculty, students, and staff.

It should be noted that the UM College of Engineering is unique in this State in its ability to attract the outstanding faculty and students necessary to achieve national leadership. Furthermore, it alone possesses the reputation to leverage this investment of State support several-fold through matching grants and contracts from both the federal government and the private sector. More specifically, the proposed investment by the State would be matched by growth in College-generated revenues to a sustained level of over \$70 million per year: \$30 million per year from federal and industrial research contracts; \$25 million per year from student tuition and fees; and \$15 million per year from private and corporate gifts such a partnership involving State,



federal, and private support is essential in achieving the level of resources necessary to compete with the nation's leading public and private institutions.

## APPENDIX B

### THE IMPACT OF THE UM COLLEGE OF ENGINEERING ON STATEWIDE ECONOMIC DEVELOPMENT

#### Background:

In recent months, several important new studies have been released which have clarified:

- o The importance of technology to Michigan's future economic development.
- o The investments that will be necessary if Michigan is to participate in this nation's long-term prosperity.
- o The role that higher education will play in this effort.

#### These studies include:

1. Putting our Minds Together: New Directions for Michigan Higher Education, The Governor's Commission on the Future of Higher Education in Michigan (the "Ross Report")
2. The Path to Prosperity, Findings and Recommendations of the Task Force for a Long-Term Economic Strategy for Michigan
3. Preliminary Recommendations, Governor's Commission on Entrepreneurship and Small Business Development
4. Route 128 and Silicon Valley: A Comparison, Peter Eckstein, Executive Director, Governor's Commission on Jobs and Economic Development

In an attempt to respond to the recommendations of these reports, the UM College of Engineering has developed a strategy for assisting in statewide economic development activities. This strategy is reviewed in this Appendix.

#### Michigan's Path to Prosperity

As pointed out by the Ross Report, a state becomes prosperous in one way only: by increasing the value of the goods and services that industries in its economic base sell outside the state. While industries such as retail trade and medical services are among the fastest growing, they do not contribute to the economic base but rather simply shift resources internally from one economic sector to another. Rather, the vast majority (90%) of Michigan's economic base lies in durable goods manufacturing. In a sense, manufacturing industry is and will remain the real strength of Michigan's "economic engine".

By combining the state's largely unskilled and semi-skilled workforce with substantial amounts of capital and technology, Michigan has made its workers the most productive and best paid in the world. However today the facilities and technology employed by unskilled labor in high volume standardized production can be purchased by manufacturers anywhere.

Hence Michigan industry must replace the standardized, routine, low-skill, mass production of familiar products, in which we can no longer complete unless we dramatically lower wage rates, with competitive new products and processes that require skilled labor. We must shift our state's economic base toward products and processes that depend on the one part of the production system that cannot be readily transferred to competing regions: human skills. These skills include those of production workers, managers, technologists, and researchers. Production processes that rely on human skills must remain where the skilled people are.

Economic prosperity for Michigan lies not in tearing down the state's old industrial base for a different kind of economy, but in helping that base make the changes necessary to compete in a new economic environment. Indeed, because of its existing agglomeration of durable goods manufacturing firms, skills, and infrastructure, Michigan possesses an advantage in the competition to become a leading world center of durable goods complex manufacturing.

Michigan must become America's factory of the future. And it must become a world center for the export of the new industrial technologies and manufacturing machinery that will form the basis of the factory of the future. In Michigan's emergence as the center of complex manufacturing, new technology will not a separate industrial sector; it will be at the heart of every industrial sector.

Our ability to innovate -- to generate and to executive new economic ideas -- must become our principal economic advantage. Only in this way can we be competitive with other regions and nations and productive enough to earn the income required for a rising standard of living. In this sense, innovation will be the energy that drives change in our state's economy.

To position Michigan as the nation's source of emerging industrial technology, we must move rapidly along three fronts:

- o To enhance the growth of research and development in Michigan.
- o To accelerate the transfer of technology into Michigan industry.
- o To develop a strong coalition within Michigan among government, industry, labor, and universities to create a "venture culture" in Michigan.

## The Importance of the UM College of Engineering

Experience in other regions suggests that Michigan's success in achieving this rebirth in its industrial base and competing effectively with other states and nations will depend on its ability to build and sustain a world-class engineering school. Such schools play a vital role in economic development since they provide the intellectual creativity fundamental to technological innovation and the talented, broadly-educated engineers capable of understanding and implementing this technology.

Furthermore, when coupled with appropriate technology-transfer mechanisms, there is little doubt that world-class engineering schools at the cutting edge of research and development can have a major impact on both technological innovation and implementation in the private sector. They provide, through their faculty, students, and graduates, the mechanism for transferring research from the campus into the private sector for commercial exploitation. Finally, such schools are usually a key factor in attracting the "risk capital" represented by massive federal R&D contracts.

Experience has also shown that only those engineering schools capable of clearly ranking among the nation's leaders are able to have a major impact on economic development. Only such world-class programs are capable of attracting the outstanding faculty, the talented students, and the massive resources necessary to achieve the required level of excellence.

For this reason, each of the major studies has stressed the importance of the UM College of Engineering in determining the future economic prosperity of our state:

1. The Ross Report has called for special emphasis on the UM College of Engineering:

"To ensure the lead position in the development of manufacturing production processes, Michigan must invest heavily in centers of applied research in industrial technology, with special emphasis on developing the University of Michigan College of Engineering as a world leader in this field."

2. The Governor's Commission on the Future of Higher Education has stressed:

"The existence of high-quality engineering programs is critical to Michigan's economic future. The Commission recommends that state funds be focused on the few high-quality engineering programs consistent with institutional roles and missions."

3. The Governor's Commission on Entrepreneurship and Small Business Development has singled out UM Engineering as a key factor in enhancing the growth of R&D in Michigan, accelerating the transfer of this technology into Michigan industry, and developing a "venture culture" in our state.

4. The Governor's Commission on Jobs and Economic Development has stressed the importance of leading engineering schools on the future of industry in our state.

There are several reasons for this focused attention on the UM College of Engineering as a major factor in Michigan's future: The College is a unique resource in this state. It alone among Michigan's institutions of higher education is within striking distance of achieving the degree of national leadership in engineering education and research necessary for major long term economic development.

The College is presently ranked 5th in reputation among the nation's leading engineering schools. It has been identified as a national center of excellence in technologies of critical importance to Michigan, including complex manufacturing technology, machine intelligence, microelectronics and optical devices, industrial engineering, computer engineering, and materials engineering. Furthermore, the 6,000 students enrolled by the College presently rank among the top 2% of Michigan's high school graduates and hence represent perhaps this state's most valuable source of "intellectual capital".

Coupled with this strong emphasis has been an increased recognition that prompt action is necessary to restore an adequate level of State support to allow the UM College of Engineering to play the role it must in establishing Michigan as the leader in emerging industrial technology. Each of these studies has called for increased commitments on the part of State government to provide the UM College of Engineering with the resources necessary to remain competitive with leading public and private engineering schools.

While such support will be a necessary prerequisite if the College is to play the critical role expected of it, there are also other steps which must be taken. The UM College of Engineering believes it has a major responsibility to respond to the needs of Michigan and its industry:

- o Through the attraction of outstanding engineers and scientists and the establishment of national research centers of excellence capable of technological innovation.
- o Through the transfer of this technology to Michigan industry through its graduates, continuing engineering education, research partnerships, and the formation of spinoff companies.
- o Through direct participation in economic development by attracting companies and national R&D centers to Michigan and encouraging its faculty and graduates to spin off new companies.

## A Strategy for Statewide Economic Development

The UM College of Engineering probably has its largest impact on statewide economic development through the over 1,800 engineers it graduates each year -- roughly 70% of whom accept positions in the Great Lakes area -- and the research achievements of its faculty and staff. However in recent years, UM Engineering has gone beyond these traditional mechanisms to initiate a number of new programs aimed at regional economic development. The College has developed its strategy in close cooperation with leaders of state government, industry, and business.

The basic strategy can be grouped into three areas:

### Technological Innovation:

- o The attraction of outstanding engineers and scientists to Michigan
- o The establishment of national research "centers of excellence"

### Technology Transfer:

- o Traditional mechanisms (graduates, consulting, publishing)
- o Research partnerships with industry
- o Continuing engineering education
- o Formation of spinoff companies
- o Industrial consortia

### Job Creation:

- o Formation of spinoff companies
- o Attraction of new companies to Michigan
- o Attraction of major national R&D centers

We will consider each component of this strategy in turn.

### Technological Innovation:

As noted by the Ross Report, "innovation is the energy that drives change in a state economy". It has also been noted that most of the significant technological innovations that stimulated industrial growth in other parts of the country originated in leading engineering schools. Hence, it is reasonable to expect that the UM College of Engineering will play (and has played) a similar role in stimulating technological innovation in Michigan.

To be a world leader in emerging industrial technology, Michigan must attract engineers and scientists of extraordinary ability and creativity. The UM College of engineering is one of the few institutions in the nation with the proven ability to attract such people.

For example, the 6,000 students presently enrolled in the College probably represents the largest concentration of students with exceptional abilities in science and mathematics of any institution in the United States. Furthermore, over the past three years the College has recruited 70 new engineering faculty from the finest institutions in this nation (Stanford, MIT, Caltech, ...).

In recent years the College has been able to build several programs which are now clearly identified as national research centers of excellence:

- Center for Research on Integrated Manufacturing (CRIM)
- Industrial Technology Institute (ITI)
- Air Force Center of Excellence in Robotics
- Computer-Aided Engineering Network
- Center for Ergonomics
- SRC Center of Excellence in Semiconductor Manufacturing

Additional major research centers under development include:

- Center for Applied Optics
- Materials Research Laboratory
- Solid-State Electronics Laboratory
- Center for Scientific Computation
- Artificial Intelligence Institute
- Machine Intelligence Center
- Applied Physics Program

#### Technology Transfer:

Traditionally, leading engineering schools such as the UM College of Engineering have transferred technology to the private sector in the following ways:

- o Placement of graduates in Michigan industry
- o Co-operative engineering education
- o Continuing engineering education for Michigan industry
- o Publication of research results in the open literature
- o Faculty/industry exchange programs
- o Faculty and staff consultation with industry
- o Special research projects conducted for industry

However, in recent years the College has gone beyond these traditional mechanisms to develop new ways to transfer technology. One of the most important mechanisms involves Industrial Affiliates Programs in which 10 to 20 companies will work with the College in areas of specific technological interest. Ongoing Industrial Affiliates Programs include:

- o Solid-State Electronics
- o Robotics
- o Ergonomics
- o Flow Reaction and Porous Media

- o Colloidal and Surface Phenomena
- o Machine-Tool Wear and Sensing
- o Information Systems Engineering
- o Computer-Aided Manufacturing
- o Construction Engineering and Management
- o Computer-Enhanced Productivity (EPIC)

The College has pioneered in the development of a more sophisticated and sustained type of relationship known as the Industrial Research Partnership. In these partnerships, the College works closely on common research problems with key companies. The College forms teams of PhD students led by faculty which then work side by side with industrial engineers and scientists (both in company facilities and on campus). Such partnerships have already yielded dramatic leaps forward in critical areas of technology. Existing research partnerships have been formed with the following companies:

- o General Motors: "factory of the future"
- o Ford: ergonomics, electronics, design
- o IBM: supercomputers and robotics
- o Intel: computer science
- o Semiconductor Research Corporation: automation
- o General Electric: computer-aided design
- o General Dynamics: computing networks

Other partnerships presently under negotiation include:

- o Chrysler: computer-integrated manufacturing
- o Dow: chemical process control
- o Bechtel: CAD in large-scale construction

#### Job Creation:

The UM College of Engineering is also involved in a number of activities aimed at direct job creation. One of the most important such mechanisms is through the formation of new "spinoff" companies by faculty, staff, and students. This has always been an active area, as evidenced by the 77 companies formed by the College and its affiliated research laboratories over the past two decades. However, strong steps are now being taken to encourage and facilitate this activity, and the rate of spinoffs is increasing rapidly.

There has also been considerable activity directed toward attracting industry to Michigan. Through close coordination with state and local government, the College has used its extensive industrial contacts to identify and interact with prospective companies. During the course of a typical academic year, faculty and staff of the College will conduct 50 to 60 day-long briefings both on campus and at industrial sites with the intent of stressing the desirability of locating new installations in Michigan. The College has also been an important partner in efforts to develop several research parks in the southeastern Michigan area.



Finally, the UM College of Engineering has frequently played a key role in attempts to attract major national R&D centers to Michigan. For example, the College provided the principal technical component of the State's proposal for siting the Microelectronics and Computer Corporation. It has taken the lead in efforts to attract the DOD Software Engineering Institute and the NSF National Supercomputer Center. Similar efforts are now underway to compete for the following centers:

- o Air Force Artificial Intelligence Institute
- o National Knowledge Engineering Center
- o NSF Materials Research Laboratory
- o DOD Strategic Defense Initiative
- o National Laser Institute
- o NSF Engineering Research Center

#### Conclusions

There seems little doubt that the UM College of Engineering represents a valuable resource to Michigan. Its role will become increasingly important as Michigan strives to diversify and strengthen its economic base with technology-based industry. In this sense, the UM College of Engineering provides state government with both a vehicle and an extraordinary opportunity for investing in the long-term economic health of our state.

## APPENDIX C

### EXAMPLES OF ACTIVITIES OF THE UM COLLEGE OF ENGINEERING RELATED TO ECONOMIC DEVELOPMENT

1. In 1981 the College established the Center for Research on Integrated Manufacturing to conduct research and instruction in areas concerned with the computer-based automation of the functions of industrial production, ranging from product design to manufacturing to management, sales, service, and upgrading -- all of the activities of the so-called "factory of the future". As the Ross Report has noted, it is just such complex manufacturing that will be the key to Michigan's long-term economic prosperity. The Center currently involves the efforts of 45 faculty and 100 graduate students from 6 academic departments. In less than three years, the Center has received international recognition as one of the leading manufacturing research programs in the nation. It has built a sustained level of funding from industrial and federal sources of roughly \$6 million per year.
2. The College played a key role in the development of the Industrial Technology Institute of Michigan. This Institute will become a world-class center for research and development in a variety of areas related to manufacturing, ranging from automation and manufacturing processes to technology transfer and the social implications of industrial technology. The Institute is currently housed in College facilities and building its initial programs with the assistance of College staff. Within a short time the Institute expects to employ roughly 200 staff and be engaged in a broad spectrum of basic and applied research and development in manufacturing.
3. In parallel with these major thrusts into industrial technology and manufacturing engineering, UM Engineering has begun an exciting new program in "white collar" or "professional" productivity, the EPIC Project (Enhanced Productivity through Integrated Computer Workstations). In collaboration with several Michigan companies, the College is working to apply modern computer and communications technology to develop a prototype computer network of tomorrow, the Computer Aided Engineering Network, that will support industry and business. Major computer companies such as IBM, Apollo, Apple, AT&T, EDS, and General Electric are active participants in assisting in the development of this system.
4. The College of Engineering conducts the leading program in the nation in occupational health and safety through its Center for Ergonomics. Recently, the Center has played a key role in analyzing and restructuring the workplace environment of the factories of one of Michigan's leading companies, in order to address the concerns both of labor and management. Of particular concern has been the development of an effective "man-machine interface" between workers and automated machines.

5. In 1984 the College began construction of the Laboratory of Electrical Engineering and Computer Science. Concurrent with this project, the College has consolidated its programs in electrical engineering, systems engineering, and computer science and engineering into one of the largest and most comprehensive Departments of Electrical Engineering and Computer Science in the nation, with almost 100 faculty and 1,800 students. Moreover, during the past two years the College has developed what is now regarded as the nation's most sophisticated university computing environment. These factors have provided Michigan with world-wide recognition for its programs in electrical engineering, computer science, and telecommunications technology -- areas of critical importance to Michigan industry.

6. In recognition of its combined strengths in solid-state electronics and industrial automation, the American electronics industry recently selected the UM College of Engineering (along with Stanford and the North Carolina Research Triangle) as the cornerstone of a major new research effort concerned with developing the technology of the microelectronics factory of the future. Since the automobile industry will be both the largest consumer and manufacturer of electronic components, this research project has an extraordinary importance for future industrial growth in the state.

7. The College has recently attracted several of the leading materials scientists in the nation to build a world-class research laboratory in advanced materials research. Eight new faculty will be added in this important area. The College is now seeking a \$6 million grant from the National Science Foundation to establish a major Materials Research Laboratory in Michigan.

8. The College has been the driving force behind the University's efforts to attract a major federally-sponsored supercomputer center to Michigan. Associated with the center will be a Center for Scientific Computation which will attract many of the leading scientists and engineers in the world to our State.

9. The College is building on its traditional strength in applied optics to establish a new Center for Applied Optics. Research areas for the Center include optical diagnostics, high-powered lasers, ophthalmological measurements, laser spectroscopy, holography, optical data processing, guided optics, coherent optical measurement techniques, and nonlinear optics. Of particular interest will be a major new program in optoelectronics -- optics on a chip. Since many believe that this technology will eventually replace microelectronics, the development of one of this nation's leading programs in this area could well trigger a Silicon Valley (more precisely, a "Gallium Arsenide" Valley) phenomenon in the southeastern Michigan area.

10. Research and instruction in artificial intelligence has been a part of many departments at Michigan. The recent creation of the Department of Electrical Engineering and Computer Science has brought together the majority of researchers in this area. The College is committed to

building a strong applied research program in artificial intelligence with special emphasis on industrial applications. Working closely with major companies such as Electronic Data Systems (recently acquired by General Motors), the College intends to build a national Institute in Knowledge Engineering, the application of artificial intelligence to manufacturing processes.

11. For many years the College has conducted Industrial Affiliates programs in which companies collaborate in a variety of technical areas of mutual interest. At present there are ten such programs in areas such as Robotics, Solid State Electronics, Machine Tool Wear, CAD/CAM, Catalysis and Surface Science. However, UM Engineering has recently negotiated several more extensive interactions, Industrial Research Partnerships, with key companies such as General Motors, IBM, and General Dynamics in which the College places faculty-graduate student teams into their facilities to identify and develop joint research projects, and then these teams return to campus, along with their industrial colleagues, to continue the research.

12. The College has taken very seriously its obligations to transfer the fruits of its research activities into the private sector to stimulate economic growth and job creation. Through a major restructuring of internal policies, the College has sought to encourage faculty and students to spin off research developments into the private sector. During the past year alone, 7 new companies have been started by faculty of the College bringing the total number started by College faculty, staff, and affiliated laboratories to 85 (see Appendix C).

13. Furthermore, the College has worked with the University to found the Michigan Research Corporation, an independent corporation, with the mission of identifying intellectual properties developed on campus and providing the guidance and resources necessary to bring these to commercial application. The College also works quite closely with a number of leading venture capital firms.

14. The College has taken steps to expand its delivery of instruction in engineering to industry through a variety of mechanisms, including its Instructional Television Network, tutored-videotape instruction, and engineering short courses and conferences held both on campus and at widely-scattered industrial sites. It is also participating with industry through co-operative education programs in a variety of fields.

15. The College has cooperated closely with state and local government in a variety of economic development activities. For example, the College was a founding member of the Michigan Technology Council. Furthermore, it has participated with the Governor's Office in efforts to attract new companies and national R&D Centers to Michigan.

APPENDIX D

SPINOFF COMPANIES ESTABLISHED BY  
UM ENGINEERING FACULTY AND STAFF

Applied Dynamics, Inc.	(Howe)
Applied Theory, Inc.	(Cole)
Arktronics	(students)
Automated Analysis Corp.	(Anderson)
CFR Inc.	(Hilliard)
Coastal Dynamics Inc.	(Meadows)
Conductron	(Siegel)
Electrocon International	(Enns)
Environmental Dynamics Inc.	(Cole, Weber)
ESZ Associates Inc.	(Edlund, Shure, Zweifel)
Explosion Research Corp.	(Kauffman)
ISDOS Inc.	(Teichroew)
Limno-Tech Inc.	(Canale)
Jodon Inc.	(Gillespie)
Michigan Automotive Research Corp.	(Cole)
Machine Vision International	(Sternberg)
Materials Technology Corp.	(Felbeck, Jones, Bolt)
Mechanical Dynamics Inc.	(Chace)
Medicus Inc.	(Jelinek)
Project Management Assoc.	(Ponce De Leon)
QED Environmental Systems	(Weber)
Raycon, Inc.	(Check, Rupert)
Solarcon, Inc.	(Clark)
Starpak Energy Systems, Inc.	(Clark)
Stoll, Evans, Woods, Consultants	(Woods)
TDR Inc.	(Felbeck)
Transidyne General	(Diamond)
Traverse Group	(Armstrong)
VAI	(Vorus)
Vector Research	(Bonder)

SPINOFF COMPANIES ESTABLISHED BY  
UM ENGINEERING AFFILIATED LABORATORIES

(Willow Run, ERIM, Space Physics Research Labs, Radiation Lab...)

Argo Science, Inc.	1976
Ann Arbor Computer Corp.	1972
Applied Intelligent Systems	1982
Arono Pemex	1969
Bendix Aerospace Division	1961
CFC, Inc.	1971
Conductron	1960
Control Data Corp.	1958
Crystal Optics Research, Inc.	1963
Cytosystems Corp.	1982
Daedalus Enterprises	1969
Data Max	1967
Data Products	1960
Data Systems, Inc.	1961
DeKalb, Inc., Sensors Div.	1974
First Ann Arbor Corp.	1967
Geospectra Corp.	1974
Harris Electro-Optics Center	1969
Hearing & Noise Assoc.	1979
Hewlett-Packard, Data Systems Div.	1964
Holly Carburetor-Rochester Div.	1957
Intelldata, Inc.	1959
Irwin Industries International	1979
Jervis Webb, Inc., AA Comp. Div.	1973
KMS Corporation	1969
KMS Fusion	1971
Kaiser Optical Systems, Inc.	1980
Laser Systems, Inc.	1967
Lear Siegler, Laser Systems Div.	1965
Machine Vision International	1983
Manufacturing Data Systems, Inc.	1962
McDonnell Douglas, Conductron Div.	1967
Michigan Computers and Instru.	1983
Nichols Research Corp.	1978
Northern Telecom, Sycor Div.	1978
Olivetti, Inc. - Irwin	1982
OptiMetrics, Inc.	1979
Photon Equipment	1957
Radiation, Inc., Adv. Optics Center	1968
Ritt Labs	1962
Sarns, Inc.	1962
Science Applications Inc. (AA Div.)	1972
Sensor Dynamics	1964
Sensors, Inc.	1969

Sonovision	1971
Strand Consultant	1965
Strand Engineering, Inc.	1960
Sycor, Inc.	1967
Synthetic Vision Systems, Inc.	1983
Trion Institute	1960
Union Carbide, Data Systems Div.	1962
Veda Corporation (Ann Arbor)	1964

## UM COLLEGE OF ENGINEERING

### FACT SUMMARY

#### REPUTATION:

- o Generally ranked 5th nationally in overall quality.
- o 18 of its degree programs are ranked in the top ten.
- o UM's programs in industrial engineering, aerospace engineering, nuclear engineering, and naval architecture are generally regarded as national leaders.

#### TRADITION:

- o UM has 7th oldest engineering college.
- o Ranks 3rd in total number of degrees awarded (50,000).
- o Pioneered in introduction of programs: metallurgical engineering (1854), naval architecture (1881), chemical engineering (1901), aeronautical engineering (1916), nuclear engineering (1953), and computer engineering (1965).

#### CAPACITY:

- o Enrollment (1984):

Undergraduates	4,512
Masters	1,041
Doctorates	539
Total	6,092
- o Degrees (1984):

B.S.	1,210
M.S.	584
Ph.D.	93
Total	1,887
- o Ranks 4th nationally both in enrollment and degrees.

#### STUDENT QUALITY:

- o 3,400 applications for 750 positions.
- o Average entering freshman ranked in 98th percentile.
- o SATs: 580 verbal, 680 math (1260)
- o Entering high school grade point average: 3.8
- o 27% of entering freshmen are straight A (4.0) students.

#### FACULTY CHARACTERISTICS:

- o 320 faculty members.
- o Over 100 new faculty will have been hired in period 198085.
- o 650 research staff.



RESEARCH ACTIVITY:

- o \$25 million per year in federally sponsored research (plus an additional \$12 million in affiliated institutes).
- o Research in all areas of science and technology.
- o Major new interdisciplinary research efforts: integrated manufacturing, microelectronics, materials processing, biotechnology, ergonomics, space systems instrumentation, applied optics, computer systems and networks, gas dynamics and combustion, supercomputers

RESOURCES:

- o Physical Plant: 1,000,000 nsf (15 buildings)
- o Equipment Inventory: \$30 million
- o Computer Network Inventory: \$20 million
- o Operating Budget:
  - Tuition Revenue \$25 million
  - Sponsored R&D \$25 million
  - Gifts \$10 million
  - State appropriation \$10 million
  - Total \$70 million

## NARRATIVE DESCRIPTION

The College of Engineering of the University of Michigan has consistently ranked among the leading engineering schools in the nation and the world, whether measured by the quality of its instructional programs, its research accomplishments, or the impact of its graduates. The College's combination of disciplinary breadth and depth of quality across the full spectrum of instruction and research make it unusual among the nation's engineering schools. Most surveys rank each of the College's undergraduate and graduate degree programs high among the leading programs in the nation.

The College is one of the few leading engineering schools imbedded in a great university with strengths across all academic and professional disciplines. This has provided it with a unique opportunity to develop new academic programs and applications involving those related fields. It has also provided students of the College with an unparalleled breadth of educational opportunities and experiences. Graduates of the College are widely known for their strong background in fundamental science and their ability to apply this knowledge in engineering practice. They move easily and rapidly into positions of leadership in industry, government, and academe.

The primary objective of the College for the decade ahead is to continue and to strengthen its position of leadership in engineering education by achieving excellence in education, research, and the professional activities of faculty, students, and graduates.

Today over 6,000 students are enrolled in the College's 20 degree programs. Each year it graduates more than 1,800 engineers at the BS, MS, and PhD levels. Ranking third among engineering schools in the total number of degrees awarded, it has more than 50,000 alumni spread throughout the world.

In recent years the College has seen an unprecedented interest on the part of the most outstanding high school graduates to enroll in its programs. For example, in 1984 the average entering freshman ranked in the 98th percentile of his or her high school graduating class. Over 25% of these students had perfect 4.0 grade point averages in high school. The College has seen a similar increase in the demand for admission to its graduate programs (particularly at the PhD level).

The College has long been a leader in the development of new academic programs at the very forefront of technology. It pioneered in the introduction of programs in metallurgical engineering (1854), naval architecture (1881), chemical engineering (1901), aeronautical engineering (1916), nuclear engineering (1953), and computer engineering (1965). This tradition of leadership continues today, as evidenced by the College's thrusts into such new areas as robotics and computer-integrated manufacturing, microelectronics, biotechnology, and

advanced materials.

The College has adopted a matrix management structure to coordinate its array of research activities. As such research efforts have demanded a broader, interdisciplinary approach involving the strong interaction of a number of traditional academic disciplines, the College has created numerous research Laboratories, Centers, and Institutes to coordinate these activities. Of particular note are major research organizations such as the Center for Research on Integrated Manufacturing, the Space Physics Research Laboratory, the Center for Ergonomics, the Solid State Electronics Laboratory, the Phoenix Memorial Laboratory, the Computing Research Laboratory, and the Ship Hydrodynamics Laboratory.

In addition, the College has developed numerous mechanisms for interacting more closely with industry. These range from a variety of Industrial Affiliates programs in which a number of companies will sponsor and participate in research in particular areas, to Research Partnerships in which the College will work closely with a particular company to develop a major research relationships involving faculty led teams of PhD students along with scientists and engineers from industry. In addition the College has spawned several research organizations separate from the University such as the Industrial Technology Institute and the Environmental Research Institute of Michigan to better facilitate industrial research. And, of course, the College continues to provide assistance to industry through cooperative engineering education programs, continuing engineering education, and its Instructional Television System.

Finally, the College of Engineering has strongly encouraged its faculty, students, and staff to become involved in the transfer of intellectual properties from the campus into the private sector. Working closely with the University, it has streamlined conflict of interest regulations to facilitate the establishment of spinoff companies. (By way of example, in 1983, faculty and staff of the College started 7 new companies.) It has also worked closely with venture capital groups, financial institutions, and the UM School of Business Administration to stimulate this important activity.

UM COLLEGE OF ENGINEERING

A TRADITION OF EXCELLENCE

SOME PARAMETERS:

- o UM has 7th oldest engineering college.
- o It ranks 3rd in total number of degrees awarded (50,000).
- o Pioneered in introduction of programs: metallurgical engineering (1854), naval architecture (1881), chemical engineering (1901), aeronautical engineering (1916), nuclear engineering (1953), and computer engineering (1965).

SOME FIRSTS OF UM ENGINEERING:

- |                             |      |
|-----------------------------|------|
| o Metallurgical Engineering | 1854 |
| o Naval Architecture        | 1881 |
| o Chemical Engineering      | 1901 |
| o Aeronautical Engineering  | 1916 |
| o Nuclear Engineering       | 1953 |
| o Computer Engineering      | 1965 |

UM COLLEGE OF ENGINEERING

CAPACITY

ENROLLMENTS (1984):

Undergraduates	4,512
Masters	1,041
Doctorates	539
Total	6,092

DEGREE PRODUCTION (1984):

B.S.	1,210
M.S.	584
Ph.D.	93
Total	1,887

ENROLLMENT PATTERNS:

Electrical and Computer Engineering	1,427
Mechanical Engineering	912
Chemical Engineering	445
Aerospace Engineering	443
Civil Engineering	391
Industrial Engineering	382
Computer Science	340

UM COLLEGE OF ENGINEERING

STUDENT CHARACTERISTICS

STUDENT QUALITY:

Selectivity: 3,400 applicants for 750 positions

Percentile Ranking: 98th percentile

SAT Scores: 580 verbal  
680 math  
1,260 total

High School GPA: 4.0 (27% of class)  
3.8 (average)  
3.5 (cutoff)

Attrition rate to graduation: 10%

OTHER STUDENT CHARACTERISTICS:

- o 23% women
- o 7% minority (3% black)
- o 74% of undergraduates from Michigan
- o 11% foreign nationals

UM COLLEGE OF ENGINEERING

NATIONAL RANKINGS

CAPACITY:

- o Enrollment: Undergraduate: 4th  
Graduate: 4th
- o Degree Production: B.S. 4th  
M.S. 4th  
Ph.D. 6th
- o Alumni: 3rd
- o Sponsored Research Volume: 7th

QUALITY:

- o Overall Quality: 5th or 6th
- o Program Rankings: 

	<u>UG</u>	<u>Grad</u>
Atmospheric & Oceanic Sciences		
Aerospace Engineering	2nd	3rd
Chemical Engineering	9th	9th
Civil Engineering	7th	8th
Computer Science & Engineering		
Electrical Engineering	5th	5th
Engineering Science	3rd	
Industrial Engineering	1st	1st
Materials Engineering	3rd	
Mechanical Engineering	4th	5th
Metallurgical Engineering	9th	9th
Naval Architecture	1st	2nd
Nuclear Engineering	1st	2nd

UM COLLEGE OF ENGINEERING

ACADEMIC PROGRAMS

DEPARTMENTS:

Atmospheric and Oceanic Sciences  
Aerospace Engineering  
Chemical Engineering  
Civil Engineering  
Electrical Engineering and Computer Science  
Industrial and Operations Engineering  
Materials and Metallurgical Engineering  
Mechanical Engineering and Applied Mechanics  
Naval Architecture and Marine Engineering  
Nuclear Engineering

DEGREE PROGRAMS:

Aerospace Engineering (BS, MS, PhD)  
Applied Mechanics (BS, MS, PhD)  
Applied Physics (MS, PhD)  
Atmospheric Sciences (BS, MS, PhD)  
Bioengineering (MS, PhD)  
Chemical Engineering (BS, MS, PhD)  
Civil Engineering (BS, MS, PhD)  
Construction Engineering (MS, PhD)  
Computer Engineering (BS, MS, PhD)  
Computer Science (BS, MS, PhD)  
Electrical Engineering (BS, MS, PhD)  
Engineering Physics (BS)  
Industrial and Operations Engineering (BS, MS, PhD)  
Manufacturing Engineering (MS)  
Marine Engineering (BS, MS, PhD)  
Materials Science and Engineering (BS, MS, PhD)  
Mechanical Engineering (BS, MS, PhD)  
Metallurgical Engineering (BS, MS, PhD)  
Naval Architecture (BS, MS)  
Nuclear Engineering (BS, MS, PhD)  
Oceanic Sciences (BS, MS, PhD)



UM COLLEGE OF ENGINEERING

RESEARCH LABORATORIES, CENTERS, AND INSTITUTES

MAJOR RESEARCH UNITS:

Automotive Laboratory  
Center for Catalysis and Surface Science\*  
Center for Ergonomics  
Center for Research on Integrated Manufacturing  
    Robotics Systems Division  
    Integrated Design and Manufacturing Division  
    Manufacturing Systems Division  
Computer-Aided Engineering Network  
Computing Research Laboratory  
Gas Dynamics Laboratory  
Great Lakes Research and Marine Waters Institute\*  
Laser-Plasma Interaction Laboratory  
Macromolecular Research Center\*  
Rehabilitation Engineering Center  
Phoenix Memorial Laboratory (Ford Nuclear Reactor)\*  
Solid State Electronics Laboratory  
Space Physics Research Laboratory  
Ship Hydrodynamics Laboratory  
Transportation Research Institute\*  
Water Resources Laboratory

RESEARCH UNITS UNDER DEVELOPMENT:

Center for Applied Optics  
Center for Scientific Computation\*  
Materials Processing Research Institute\*

\*Intercollege activity

UM COLLEGE OF ENGINEERING  
RESEARCH AREAS OF MAJOR THRUST

TRADITION OF NATIONAL LEADERSHIP:

Aerospace Engineering  
Applied Optics  
Atmospheric Sciences  
Gas Dynamics  
Image Processing  
Industrial Engineering (ergonomics, operations research)  
Naval Architecture  
Nuclear Engineering  
Remote Sensing  
Thermal and Fluid Sciences  
Solid State Electronics (sensors, microwaves)

MISSION FOR NATIONAL LEADERSHIP:

Integrated Manufacturing  
Materials Processing Technology  
Biotechnology  
Computer Science and Engineering

POTENTIAL FOR NATIONAL LEADERSHIP:

Applied Mechanics (micromechanics)  
Advanced Scientific Computation (supercomputers)  
Construction Engineering  
Electronic Materials  
Modern Optics (optoelectronics, nonlinear optics)  
Polymer Process Engineering

UM COLLEGE OF ENGINEERING  
KEY INTERDISCIPLINARY THRUST AREAS

Engineering and LSA:

Computer Science and Engineering (CCS + ECE --> EECS)  
Applied Physics (Physics, Nuclear, ECE, MME)  
Materials Research (Physics, Chemistry, MME, ChE)  
Numerical Analysis and Scientific Computation (Eng, Math)  
Earth and Planetary Sciences (A&OS, Geo Sci)  
Biotechnology (Bio Sci, Chem, ChE, ECE)

Engineering and Medicine:

Biotechnology (Med, ChE, ECE)  
Image Processing (Med, ECE, Nuclear, MEAM)  
Biomechanics (Med, MEAM)

Other Interactions:

Ergonomics (Eng, Pub Health, Med)  
Biochemistry (Eng, Phar, Med)  
Computer Networks (Eng, LSA, Bus Ad, Med)  
Transportation (Eng, Pub Health, UMTRI)  
Water Sciences (Eng, LSA, Pub Health, Nat Res, GRMLK)

