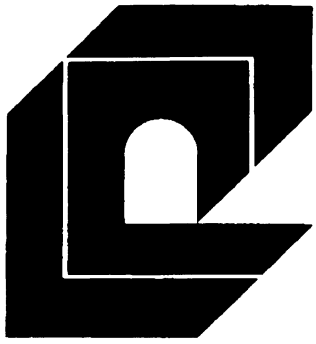

COLLEGE OF ENGINEERING
THE UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

A UNIQUE OPPORTUNITY FOR MICHIGAN'S FUTURE: AN INVESTMENT IN ENGINEERING EXCELLENCE

Rationale and Plan

February 1985

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THE PREMISE:

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 the technological innovation and entrepreneurs necessary to build new industry. These schools furthermore provide the outstanding engineering graduates necessary to sustain and strengthen the competitiveness of existing industry.

It is reasonable to expect that the role of leading engineering schools will be even more critical in a future increasingly dominated by science and technology. 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 new jobs necessary for our State's long-term prosperity will depend on its success in building and sustaining such an institution.

Michigan's Path to Prosperity:

There is growing recognition that the key to the long-term economic prosperity of Michigan will involve a major transition to "knowledge-based" activities, relying more than ever on intellectual capital. This shift will require a massive infusion of technology, both to revitalize and diversify existing Michigan industry and to spawn and attract new industries over the longer term.

While the engine driving Michigan's economy will remain durable goods manufacturing, this industry must shift rapidly to complex manufacturing processes less vulnerable to low-wage competition. Michigan must become 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 base of this state's economy in the near term, it is essential that Michigan stimulate and nurture the growth of new industries which will diversify and strengthen its economy for the long term. It is logical to expect that advanced technology and innovation will play the key role in building 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 this effort will be the availability of technological innovation, technical manpower, and the entrepreneurs capable of exploiting these resources.

The Importance of Engineering Excellence:

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.

Experiences Elsewhere:

Other regions have long recognized the important roles that institutions with world-class programs in science and engineering play in economic development. California has benefited enormously from the impact of key institutions such as Stanford and UC-Berkeley (electronics and biotechnology) and Caltech and UCLA (aerospace and defense).

A similar pattern is found in the economic revitalization of New England. Indeed, when asked to summarize the key to the economic growth in Massachusetts, a Harvard Business School professor responded with the reply, "Simple,...MIT!"

The dominant role played by world-class engineering schools in economic development has been identified in study after study. In the instances of 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 in many cases attracted the federal funding necessary to stimulate such industrial development.

Similarities and Differences:

There are both similarities and differences between Michigan and these regions. Like New England, Michigan faces the challenge of strengthening and diversifying its industrial base if it is to stabilize and sustain economic prosperity. As a highly industrialized state, Michigan is heavily dependent upon technology and therefore quite sensitive to technological change and international competition. Although Michigan has traditionally been characterized by a highly-skilled labor force, those skills are becoming of diminishing relevance as new technologies such as robotics, artificial intelligence, and computer-integrated-manufacturing are introduced. Michigan industry will, of necessity, become less capital- and labor-intensive and become increasingly "knowledge-intensive".

There are important differences as well. The development of the economic bases of California and New England was heavily dependent upon federal contracts (particularly R&D and defense activities). Furthermore, each region had ready availability of venture capital to spawn new industrial growth. However, it should also be noted that each of these factors was stimulated and enhanced to a major extent by the key engineering schools of these regions.

There is also an important difference in the manner in which these regions have approached the long-term investments necessary for technological strength. Both California and New England have invested heavily through public and private mechanisms in building the leading engineering schools in this nation. At one time Michigan also recognized the importance of such investments. In the years following World War II, this State made the commitments necessary to build one of the leading engineering schools in the nation. The UM College of Engineering and its affiliated organizations such as the Willow Run Laboratories played a major role in providing the research output and engineering graduates to strengthen and diversify Michigan industry.

Yet, roughly 20 years ago, Michigan took a dramatically different turn from other states by throttling back its support for engineering education. Despite the obvious importance of world-class programs in science and engineering for economic development, our State pursued a course precisely opposite to those taken by other states. It responded to the challenge of high technology, the intense competition presented by other states attempting to attract or spawn such industry -- our industry in many cases -- by drastically cutting public support for its major engineering institution, the UM College of Engineering.

While it is true that the blueprint for economic development will be somewhat different for Michigan, it is also clear that a key component in any strategy must be strong public support for the State's leading engineering school, the UM College of Engineering. Indeed, it will be such world-class schools which will provide the technological innovation and talented engineers necessary for long-term economic prosperity. Moreover, it is now painfully clear that in a future increasingly dominated by science and technology, states which are unable or unwilling to make the long-term investments necessary to develop and sustain such world-class institutions simply will be unable to compete for the economic prosperity of tomorrow.

THE OPPORTUNITY:

The UM College of Engineering 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 impact.

Status of the UM College of Engineering:

The College has been singled out by the federal government, the State of Michigan, and the University of Michigan as a key element in the economic strength of the Great Lakes area. Such a role is consistent with the present reputation and capacity of the College:

Reputation: Ranked among the top five engineering schools in the nation (with MIT, Stanford, UC-Berkeley, and Illinois)
Capacity: 6,000 students, 320 faculty (3rd in the nation)
Productivity: 1,000 BS, 550 MS, and 100 PhD degrees per year
Research: $20 million per year (federal and industrial contracts)
Student Quality: 98th percentile (1280 SATs)
Faculty Quality: Outstanding (active and aggressive)
Physical Plant: Rapidly improving
Entrepreneurial Environment: Rapidly improving
Laboratory Equipment: Seriously deficient
Base Funding: Seriously deficient

TABLE 1

RANKINGS OF ENGINEERING SCHOOLS ACCORDING TO GOURMAN RATINGS

All Grad Programs	All UG Programs	Select Grad Programs
MIT	**Michigan**	MIT
UC-Berkeley	UC-Berkeley	Stanford
Michigan	MIT	UC-Berkeley
Stanford	Stanford	Illinois
Illinois	Illinois	**Michigan**
Caltech	Minnesota	Caltech
Wisconsin	Cornell	Princeton
Princeton	Princeton	Purdue
Purdue	Columbia	Cornell
Cornell	Purdue	Minnesota
Minnesota	Wisconsin	Wisconsin
Columbia	Penn State	Columbia

1. Rankings determined from **all graduate** programs in which Michigan is rated.

2. Rankings determined from **all undergraduate** programs in which Michigan is rated.

3. Rankings determined from **core graduate programs only** (i.e., Aerospace, Chemical, Civil, Electrical, Industrial, Mechanical, and Metallurgical).

Economic Impact:

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

- Each year the College graduates over 1,800 engineers, over 70% of whom remain in the Great Lakes area.
- UM Engineering has been recognized as a national center of excellence in several areas of importance to Michigan, including complex manufacturing technology, ergonomics, advanced electronics and optics, and computer engineering.
- The College has formed important research partnerships with Michigan companies across a broad range of technologies.
- 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.
- UM Engineering faculty and staff are accelerating the rate at which they spin off new companies (seven last year).
- The College has worked closely with both state and local government in attracting new industry to Michigan.

Unique Opportunities:

The College of Engineering has been presented with a number of unique opportunities to achieve national leadership in areas of major importance to Michigan's future:

- By building on the momentum established through its Center for Robotics and Integrated Manufacturing and the Industrial Technology Institute, the College has established itself as one of the nation's leading centers for research on complex manufacturing processes. Strong technical relationships with Michigan industry have already yielded important productivity gains.
- In the Spring of 1984, the College began construction of the State-funded 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 complete Departments of Electrical Engineering and Computer Science in the nation (with over 100 faculty and 1,800 students). Moreover, during the past year the College has managed to develop what is now regarded as the nation's most sophisticated university computing environment (the Computer Aided Engineering

Network). These factors are providing Michigan with world-wide recognition for its programs in electrical engineering, computer science, and telecommunications technology -- areas of critical importance to Michigan industry.

- 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, UM Engineering is working to apply modern computer and communications technology to develop a prototype computer network of tomorrow, the Computer Aided Engineering Network.

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

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

- The College has been successful in attracting several of the world's leading scientists in opto-electronics ("lasers on a chip") as the cornerstone of its newly formed Center for Applied Optics. Since many believe that this area will eventually replace microelectronics, the development of one of this nation's leading programs could well trigger a Silicon Valley (more precisely, a "Gallium-Arsenide" Valley) phenomenon in the southeastern Michigan area.

- The College is working closely with industry (particularly General Motors and Electronic Data Systems) to build a national center of excellence in the areas of artificial intelligence and machine intelligence. This technology will have a profound impact on the future of manufacturing activities in Michigan.

- The College has recently spearheaded an effort to attract a major federally-sponsored supercomputer center to Michigan. Several such computer centers will be funded over the next several years in an effort to stimulate both scientific and industrial uses of these machines. The economic spinoff of such a national supercomputer center on our State would be extensive.

- 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 1983-84 fiscal year seven new companies were started by College faculty. We expect this number to double during 1984-85.

- Over the next several years the College will have an unusual capacity to add new faculty to its ranks. By implementing aggressive recruitment programs, the College will be able to attract extraordinarily talented and innovative faculty into areas critical to our State's future.

Today UM Engineering is in an excellent position to achieve national leadership in areas of major importance to Michigan's future including machine intelligence (artificial intelligence), materials processing technology, optoelectronics, computer science, biotechnology, and telecommunications technology. However, if the College is to have the capacity to respond to such opportunities, it will require direct and immediate assistance from the State of Michigan to restore an adequate base level of support for its programs.

THE CHALLENGE:

The UM College of Engineering provides Michigan with both a vehicle and an extraordinary opportunity for investing in the long-term economic health of our State. Michigan should seize this opportunity by acting now to restore the College's capacity to respond to the needs of existing industry and to provide the technological innovation and engineering graduates necessary to attract and build new industry.

Background:

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, Texas, Arizona, New York, along with many others have made massive commitments of public funds to build the Berkeleys and the Stanfords, the MITs and the Michigans of tomorrow. They have recognized the critical role that will be played by higher education in general and engineering education in particular as our economy (indeed, our very society) becomes ever more dependent on science and technology and therefore upon engineers.

However, these states have also recognized that the traditional mechanism of allocating resources to fund institutions of higher education is simply not adequate to build the centers of excellence required for major economic impact. The lesson is clear. Only programs at the cutting edge of technology which are capable of ranking among the nation's leaders are capable of a major impact on economic development in this State. Only such world-class programs are capable of attracting the outstanding faculty, students, and economic and technological resources necessary to stimulate the growth of new industry.

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 to act 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 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 led to an equipment and computer inventory backlog now estimated at over $70 million.

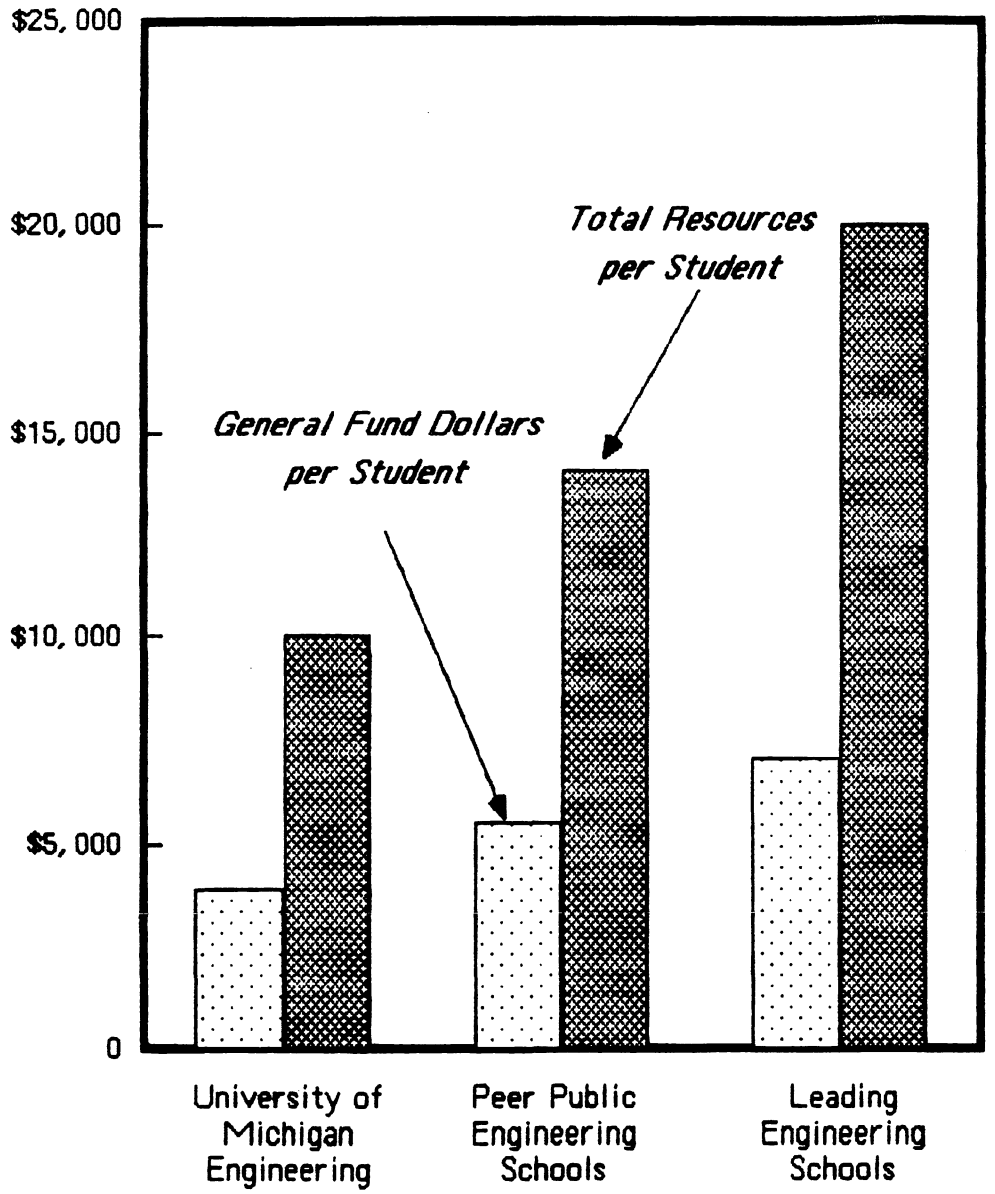
The Crisis:

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

Despite its central importance to economic development in Michigan, the level of public support of the UM College of Engineering has now dropped to not only the lowest of any of its peer institutions, but to one of the lowest levels of support for any academic unit in this State. To calibrate the magnitude of this crippling degree of 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, Florida, Maryland,...) Furthermore, the bulk of this General Fund support for the UM College of Engineering now must be derived from tuition fees and contract research -- not from State appropriations, which now amount to less than $1,000 per student-year.

The disparity with leading engineering schools is even more alarming. 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 seems evident that unless this serious funding gap is erased, the UM Engineering College will find it increasingly difficult to compete for the faculty and the other resources necessary to achieve the national leadership necessary for maximum economic impact.

A Comparison of Support per Student in Engineering Education



The Inadequacy of Traditional Appropriation Mechanisms:

Michigan has long prided itself on the autonomy it has granted its institutions of higher education. It has relied on the wisdom of these institutions in the deployment of state resources for the support of programs of high priority to Michigan citizens. In a sense, the state has adopted the "trickle down" theory of funding academic programs: The state provides a general, undesignated allocation to each institution, and then depends upon that institution to channel these resources to programs of most critical importance.

Unfortunately, the present crisis faced by engineering education in Michigan in general and the UM College of Engineering in particular provides strong evidence that such a trickle-down process simply does not work to target state priorities -- particularly when it is coupled with the "across-the-board" incremental funding patterns which have characterized the support of higher education in Michigan in recent years. It is now clear that our State's traditional methods of funding higher education are simply not adequate to focus resources to achieve the necessary level of excellence in programs critical to the future of this State. Extraordinary measures are now required.

It is just such an extraordinary plan of action that must be implemented if the UM College of Engineering is to participate to the degree it should in the strengthening and diversification of Michigan's future.

THE PLAN:

If the University of Michigan College of Engineering is to have the capacity to participate as it must in establishing Michigan as the leader in emerging 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, and industry, have developed the following two-stage plan for special action:

Basic Strategy:

Stage 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 (e.g., Illinois, Purdue, Minnesota, Arizona, Texas). 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 additional 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 College's laboratory equipment inventory to competitive levels. In addition, two new physical facilities would be required: a $20 million building to contain laboratories for rapidly changing areas of technology, and a $20 million facility to serve as a incubation center for bringing together startup company and satellite corporate R&D laboratories with College faculty, students, and staff.

Specific Components of the Plan:

Stage I. The Restoration Phase:

Annual Base Budget Growth Requirements: $8.5 million

An increase in the College's General Fund support to a level comparable to peer public institutions (e.g., Illinois, Purdue, Minnesota, Arizona):

$5 M	Faculty and technical support staff
$3.5 M	Sustained laboratory equipment support

One-Time Equipment Support Requirements: $20 million

$8 M	Solid State Electronics Laboratory
$7 M	Materials Research Laboratory
$3 M	Center for Applied Optics
$2 M	UM Engineering Television Network

Stage II. The Leadership Phase:

Additional Base Budget Growth: $9.5 million

$5 M	Faculty and support staff
$4.5	Sustained equipment and computing support

Additional One-Time Equipment Support: $20 million

Additional investments to restore the College's laboratory equipment (decimated during the erosion of State support during the 1970s) and respond to federal and industrial matching grant opportunities

$15 M	Restoration of lab equipment inventory
$ 5 M	Startup equipment for new faculty

Physical Facilities:

Additional physical facilities to support major new experimental initiatives in key areas such as opto-electronics, materials processing research, and integrated manufacturing:

$20 M Flexible experimental laboratory facility

Technology Transfer:

Funding to support special programs to facilitate technology transfer and an aggressive entrepreneurial environment:

$20 M Incubation center for spinoff companies (privately financed)

Institutional Matters:

- College control over all contract research funding (both direct and indirect cost recovery via an Engineering Research Institute model)
- Some degree of control over other College-generated resources and expenditures (e.g., tuition revenue and patent and royalty income)
- Modification of University conflict-of-interest and patent policies.

Additional Sources of Support:

The UM College of Engineering 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 a growth in College-generated revenues to a sustained level of over $70 million per year:

$30 million per year	federal and industrial research contracts
$25 million per year	tuition and fees
$15 million per year	private gifts

Such a partnership between 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. (See Table 2 on the following page for a more detailed analysis of the proposed resource distribution among State, federal, and private sources.)

TABLE 2

PRESENT AND PROPOSED INVESTMENTS IN THE UM COLLEGE OF ENGINEERING

OPERATING FUNDS ($millions per year)

Source	Present	Proposed	Increment
Federal (Research)	$15 M/y	30	15
Tuition	22	25	3
Private Gifts	5	10	5
Industrial Grants	5	10	5
State Support	7	25*	15
Total	$54 M/y	$100 M/y	$43 M/y

*Total State appropriation of $4,200 per student-year

FACILITIES AND EQUIPMENT ($millions)

Source of Funds	Present Value**	Proposed Outlay
Private		
Buildings	$41.0	$20
Equipment	12.5	
Federal		
Buildings	1.5	10
Equipment	3.6	
State		
Buildings	39.9	20
Equipment	2.4	40
	$100.9 M	$90 M

**Original construction cost of buildings plus 5-year expenditure on equipment.

THE IMPACT:

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 at this point in time 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 builders of Michigan industry. Not only will they sustain the competitiveness of existing Michigan companies, but they will found the new companies necessary to diversity Michigan's economic base.

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

The required incremental investment ($8.5 million in sustained annual funding and $20 million in capital outlay in the "restoration phase" of Stage I, followed by an additional investment of $9.5 million in base and $60 million in capital outlay in the "leadership phase" of Stage II) is modest compared to the economic impact that would result from the presence of a world-class engineering school in Michigan. Graduates, faculty, and staff of the UM College of Engineering will be key factors in strengthening the competitiveness of existing Michigan industry. But of even more importance, the research activities of the College would spawn and attract new industry to diversify Michigan's economic base.

Roughly 70 years ago, the automotive 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 innovation, 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 the UM College of Engineering must be viewed as one of the most important investments Michigan can make for its long-term economic prosperity.

TABLE 3

PROPOSED SCHEDULE OF INVESTMENTS

Table 3 shows the schedule of proposed state budget support to the College of Engineering. The main items include:

- An additional base budget allocation of $18 million per year for staffing and maintenance of equipment and computer inventories.
- One-time allocations of $40 million for equipment to respond to unique opportunities in a range of technical areas including flexible manufacturing, microelectronics, computer engineering, materials research, and biotechnology.
- Capital outlay for new facilities ($20 million from State funds and $20 million from private sources).

SUSTAINED (BUDGET-BASE) GROWTH (in millions)

	Year 1	Year 2	Year 3
Staffing	$5	$3	2
Laboratory Equipment	$2	$2	--
Computing Environment	$1.5	$2.5	--

ONE-TIME CAPITAL OUTLAY (in millions)

	Year 1	Year 2	Year 3
Laboratory Equipment	$5	$5	$5
Microelectronics Lab	$4	$2	$2
Materials Research Lab	$3	$2	$2
New Faculty Programs	$1	$2	$2
Applied Optics Lab	$1	$2	--
Instructional TV Network	$2	--	--

RESEARCH FACILITIES (Building) (in millions)

	Year 1	Year 2	Year 3
Exper. Projects Facility	$12	$8	--
Incubation Center	--	--	--

TABLE 4

THE PAYOFF: NEAR TERM

Four major immediate benefits would result from the proposed investment by the State.

An adequate level of funding would be restored to allow the University of Michigan to compete with the best public and private engineering colleges for faculty, students, and resources (including federal R&D contracts, industrial support, and private gifts).

Michigan would keep pace with the efforts made by other states to build world-class engineering schools to stimulate economic development.

A clear message would be sent that not only is Michigan on the move again, but that our State also recognizes the investments that must be made to attract and sustain technology-based industry.

Finally, the College would have the resources to proceed at once with several important initiatives, including:

NSF Engineering Research Centers
NSF-DOD Materials Research Laboratory
SRC Center of Excellence in Manufacturing Sciences
National Supercomputer Center
Artificial Intelligence Institute
DOD Strategic Defense Initiative
Michigan Research Corporation - Venture Capital actions
Limited research partnerships with the private sector
Major program in optoelectronics ("lasers-on-a-chip")
MSE/MBA program in small high-tech business formation
State-wide Engineering Television Network
Major industrial partnerships
UM Engineering - ITI relationship

TABLE 5

THE PAYOFF: LONG TERM

The long-term benefits of the proposed investment by the State would be many:

- The necessary foundation would be established to make Michigan the flexible manufacturing center of the nation.
- Michigan industry would be provided with the intellectual capital (engineers and entrepreneurs) necessary to sustain competitiveness.
- Michigan industry would also be provided with the R&D base necessary for technological innovation.
- The State would have made a major investment in its most valuable resource: its top high school graduates.
- The College would produce thousands of engineers capable of meeting the needs of Michigan industry or starting up new companies.
- Research partnerships with industry would stimulate the competitiveness of large companies and would be a key to the survival of hundreds of small Michigan companies.
- This investment would stimulate a major growth in federally sponsored R&D activities in Michigan.
- It would seed the growth of several new industries:
  Complex manufacturing processes
  Optoelectronics ("Gallium Arsenide Valley"?)
  Machine intelligence
  Laser machining
  Solid-state sensors
  Materials processing
  Biotechnology
- The UM College of Engineering would be firmly established as the leading public engineering school in the nation.
- As such, the College would be able to attract the most outstanding faculty and students, as well as the resources necessary to sustain this critical level of excellence.
- Such an investment would keep the best graduates in the State, thereby preserving Michigan's intellectual capital.

APPENDIX A

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:

- The importance of technology to Michigan's future economic development.
- The investments that will be necessary if Michigan is to participate in this nation's long-term prosperity.
- 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
2. The Path to Prosperity, Findings and Recommendations of the Task Force for a Long-Term Economic Strategy for Michigan (the "Ross Report")
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:

- To enhance the growth of research and development in Michigan.
- To accelerate the transfer of technology into Michigan industry.
- 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:

- Through the attraction of outstanding engineers and scientists and the establishment of national research centers of excellence capable of technological innovation.

- Through the transfer of this technology to Michigan industry through its graduates, continuing engineering education, research partnerships, and the formation of spinoff companies.

- 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:

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

Technology Transfer:

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

Job Creation:

- Formation of spinoff companies
- Attraction of new companies to Michigan
- 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:

- Placement of graduates in Michigan industry
- Co-operative engineering education
- Continuing engineering education for Michigan industry
- Publication of research results in the open literature
- Faculty/industry exchange programs
- Faculty and staff consultation with industry
- 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 work with the College in areas of specific technological interest. Ongoing Industrial Affiliates Programs include:

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

- Colloidal and Surface Phenomena
- Machine-Tool Wear and Sensing
- Information Systems Engineering
- Computer-Aided Manufacturing
- Construction Engineering and Management
- 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:

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

Other partnerships presently under negotiation include:

- Chrysler: computer-integrated manufacturing
- Dow: chemical process control
- 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 85 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:

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

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 techology -- areas of critical importance to Michigan industry.

6. In recognition of its combined strengths is 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 federal agencies 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, opthmological 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 prolicies, the College has sought to encourage faculty and students to spin off research developments into the private sector. During the past year along, 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 oncampus 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 C

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